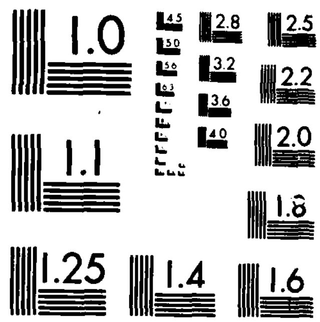
AD-A165 177 AN APPLICATION OF COST RISK IN INCENTIVE CONTRACTS(U) 1/1
NAVAL POSTGRADUATE SCHOOL MONTEREY CA C M MCGRATH
DEC 85

UNCLASSIFIED F/G 14/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN APPLICATION OF COST RISK
IN INCENTIVE CONTRACTS

by

Christopher Michael McGrath

December 1985

Thesis Advisor: Willis R. Greer Jr.

SECURITY CLASSIFICATION OF THIS PAGE

AD-A165177

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release, distribution unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: Naval Postgraduate School 6b OFFICE SYMBOL (If applicable): Code 54	7a. NAME OF MONITORING ORGANIZATION: Naval Postgraduate School
6c ADDRESS (City, State, and ZIP Code): Monterey, California 93943-5000	7b. ADDRESS (City, State, and ZIP Code): Monterey, California 93943-5000
8a NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
AN APPLICATION OF COST RISK IN INCENTIVE CONTRACTS

12 PERSONAL AUTHOR(S)
McGrath, Christopher M.

13a TYPE OF REPORT	13b TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Master's Thesis	FROM ______ TO ______	1985 December	96

16 SUPPLEMENTARY NOTATION
thesis — fr back

17 COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Cost Estimates, Incentive ~~Contracts~~, ~~Motivation~~n, Cost Analysis, Risk Analysis.

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

This ~~pape~~r begins with an examination of the literature concerning incentive contract effectiveness and contractor motivation. Citing the most frequently supported conclusions, the researcher integrates these with a cost risk analysis methodology based upon the Beta distribution. The result is a share curve that automatically adjusts the share ratio based upon estimated cost variance.

The researcher suggests that this approach is better at reflecting cost risk than the standard linear design. The share curve provides more risk sharing, especially at higher levels of cost variance, and provides both significant rewards and penalties only for significant deviations from target cost. The final conclusion is that

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Willis R. Greer Jr	22b. TELEPHONE (Include Area Code): 408-646-2161 22c. OFFICE SYMBOL: Code 54

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

the share curve mitigates the defense contractors' "risk averse" nature, thus allowing the profit motive to become operative in incentivizing the contractor to control or reduce costs. Keywords:

Approved for public release, distribution unlimited.

An Application of Cost Risk in Incentive Contracts

by

Christopher Michael McGrath
Lieutenant Commander, United States Navy
B.A., Cornell University, 1976

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1985

Author: Christopher M. McGrath
Christopher M. McGrath

Approved by:
Willis R. Greer, Thesis Advisor

Ray W. Smith, Second Reader

Willis R. Greer, Chairman
Department of Administrative Sciences

K.T. Marshall
Kneale T. Marshall
Dean of Information and Policy Sciences

ABSTRACT

This paper begins with an examination of the literature concerning incentive contract effectiveness and contractor motivation. Citing the most frequently supported conclusions, the researcher integrates these with a cost risk analysis methodology based upon the Beta distribution. The result is a share curve that automatically adjusts the share ratio based upon estimated cost variance.

The researcher suggests that this approach is better at reflecting cost risk than the standard linear design. The share curve provides more risk sharing, especially at higher levels of cost variance, and provides both significant rewards and penalties only for significant deviations from target cost. The final conclusion is that the share curve mitigates the defense contractors' "risk averse" nature, thus allowing the profit motive to become operative in incentivizing the contractor to control or reduce costs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. RESEARCH OBJECTIVE

The use of incentives in DOD contracting is not a recent development. Incentive type contracts were used in the construction of the ironclad Monitor during the Civil War, and in the development of early aircraft by the Wright brothers in 1908. Used extensively during World Wars I and II, incentive contracting had its heyday during the 1960s under then Defense Secretary McNamara. With the advent of this interest however, a significant research effort begin to focus on the effectiveness of incentive arrangements. Many studies indicated that there existed no statistical relationship between cost outcome and the incentive applied (i.e., the sharing ratio). Those researchers who did find some tendency towards cost efficiency conceded that the effect was weak.

Included in many research conclusions though, was observations by many in the field that the fault lay not in the concept of the incentive contract itself, but in poor application, inappropriate incentives, and overall poor structure.

Related studies in contractor motivation revealed many factors impacting contractor performance that were largely ignored within the incentive contract as motivators. Items such as company survival, growth, product quality, and cashflow, among others, were seen to be just as important as profit. The

importance of understanding the tradeoffs that contractors were making between these extracontractual goals was often lost in the construction of the incentive itself. Many became doubtful that effective cost incentives were possible utilizing sharing formulas, as the emphasis was on the profit motive alone.

Other research looked at the cost risk in defense contracting, how to estimate it, and its impact on the contracting process. Defense contractors were characterized as a "risk averse" group, consistently trading lower profits in the long run for cost protection in the short run. In the attempt to maintain a steady flow of government business, the quality of the product was seen to be key. Thus cost as well as schedule became secondary contractual concerns.

When attempting to apply all of these relevant findings to an effective incentive design, one can justifiably conclude that there is no consensus on any "best ways" to structure cost incentives, but a strong one for doubting their efficacy.

This researcher believes however, that the bulk of the work done on incentive contracting has concentrated too much on the aggregate performance of the contracts studied, and thus has failed to identify those factors that make for a successful application of cost incentives. Factors such as the state of the economy and the DOD budget, the size of the contract and the contractor, the type of product, stage of development, and risk, have yet to be factored out and separately studied as to how they

effected final outcome. The lack of this approach has resulted in a general dismissal of the incentive contract as an effective motivator of cost efficiency.

This researcher feels that structuring a good incentive arrangement is a difficult proposition, perhaps the most challenging of the contract types. To do it properly requires an eyes open approach that recognizes each situation as unique. The applicability of the incentive tool should be continually questioned, given the effect of some of the aforementioned factors on the arrangement. Even when a successful incentive arrangement is pointed out, many researchers will contend that it is because of inflated target costs, or due to intense government management. This researcher believes however, that if the patterns of past success are studied, certain combinations of factors would dictate certain applications of risk in the incentive structure. Particular applications under specific situations would tend towards effective motivation of cost efficiency and successful outcome.

The objective of this study is to take an in depth look at the existing work in this area, and attempt to develop a new approach to structuring the incentive arrangement. The focus will be on the share ratio, with an eye to applying certain important environmental factors, as well as integrating more risk sharing in the design process. This will involve a broader application of environmental factors in the choice of the

incentive tool, and the use of a nonlinear sharing function about target cost to better spread risk.

B. RESEARCH QUESTIONS

The primary research question is, "Do the present methods of structuring cost incentives, based on linear share functions, adequately consider cost risk, and effectively motivate contractors towards cost efficiency."

Subsidiary research questions considered are:

(1) What factors need to be considered when applying risk in the design of incentive contracts?

(2) Can these factors be quantified in any systematic manner?

(3) How can appropriate risk factors optimally be applied in the incentive arrangement to effectively motivate contractors to cost efficiency?

(4) Is there a better method in establishing a sharing ratio than the linear approach?

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this study is restricted to cost incentives, applying research based primarily on DOD incentive contracts. The focus will be on integrating research findings on incentive contract effectiveness and contractor motivation with cost risk analysis techniques, resulting in a new method of structuring cost incentives.

The study will be limited by the fact that data on target costs to actual contract outcomes is difficult to collect for proper independent analysis. The researcher will depend on the methods and analyses of previous researchers in the field,

identifying and ignoring those whose rigor and methodology were questionable. This approach will provide the base to build from.

This study is based upon the assumption that the majority of DOD and industry contractors are honest members of their profession, who actively seek contractual performance that will fulfill the standard of providing a good product on time, and at a fair and reasonable price. This win/win approach necessarily views the defense contract as a risk sharing instrument to some degree, and those in the field not subscribing to this approach may find this researcher's approach invalid, and the results superfluous.

D. RESEARCH METHODOLOGY

The methodology used for this study involved a rigorous literature search in the areas of incentive contracting, contractor motivation, and cost risk analysis. Viewpoints thus developed were further refined by attendance at two professional workshops, one in Risk Management (National Contract Management Association Spring Symposium, Golden Gate Chapter - May 1985), and the second in Advanced Concepts in Cost Estimating (Technical Marketing Society of America workshop - July 1985). The study of the literature base compiled, plus the interaction with both government and industry professionals during the workshop and symposiums provided the basis for the findings and conclusions.

E. ORGANIZATION OF THE REPORT

The report has five chapters. Chapter I is the introduction to the study. Chapter II deals with the research results in incentive contracting effectiveness, as well as contractor motivation. The significant common findings and their possible interrelationships are also explored as a basis for the risk analysis concepts discussed in Chapter III. There the important aspects of risk in defense contracting are discussed alongside the important research findings to consider in assessing risk and structuring an incentive contract. Chapter IV will integrate these three main areas of concern: research findings, risk analysis, and cost incentive design; and present an alternative sharing arrangement that this researcher feels would be more effective in incentivizing cost efficiency. The final Chapter V will present a summary with general conclusions.

II. INCENTIVE CONTRACTING AND CONTRACTOR MOTIVATION

A. RESEARCH FINDINGS

In 1980, Dr. John Kennedy of Notre Dame conducted a three year study entitled "Incentive Contracts and Cost Growth" for the Air Force Business Research Management Center. [Ref. 1] It was a massive effort consisting of:

(1) a complete literature review and documentation in the areas of incentive contract effectiveness and contractor motivation.

(2) interviews with key government and industry personnel.

(3) a series of small conferences and workshops with industry and government personnel.

(4) a pilot study of two representative companies in which actual incentive contracts were tracked to assess their effects within the company structure.

The literature review provided evidence for fourteen hypotheses that were further validated in the other phases of the study.

The intention of the researcher is to review these hypotheses, their related findings, and conclusions that are relevant to the framework being developed in this study. At that point, a few finer points from separate pieces of research examined by the larger study will be highlighted to round out the base from which to build and proceed to the topic of cost risk analysis.

Each hypothesis will be stated, with the relevant findings and conclusions following in summary format.

B. THE HYPOTHESES

1. "Contract type is not the determining variable in contract outcome." [Ref. 1: p. 15]

There were indications that some correlations could exist between contract type and how company managed a program, with a concurrent but moderate effect on company behavior. In only about 50% of the studies was a strong correlation found between contract type and actual contractor performance. The conclusion is that contract type is not the determining variable in contractor performance. Extra contractual factors such as company survival, growth, market share, cash flow, future business, and avoiding the risk of loss, play as important if not more important a role in determining contract outcome. Contractors considered the contract as a definition of parameters such as delivery, specifications, and program requirements, within which the contractor had to work. In regards to actual expenditures however, the contract was seen as establishing only an upper dollar limit, not a firm target. In summary, though specific contract type can influence behavior, it must be adapted to the company, the requirements of the contract itself, and consider extra contractual factors and their related effects.

2. "Most incentive contracts end up near target." [Ref. 1: p. 37]

After adjusting for changes, most all incentive contracts end up within a cost envelope of 7% of target (plus or minus). Some correlation exists between share ratio and cost outcome in that higher share ratios did tend to restrict overruns, especially if

the share was steeper than 70-30. CPIF contracts tended to overrun more than FPIF. The tendency for contractors to spend to target was noted, as well as attempts to negotiate both contract design and target to protect themselves against possible losses. Cost targets for incentive contracts appear to be higher than other contract types. Defense contractors are characterized as risk averse, meaning that they will opt for lower profits in exchange for cost protection. The general conclusion is that the present system drives the incentive contract to target. It is unlikely that significant cost savings can be generated in the short run. Contractors avoid large underruns as much as large overruns, and may be willing to incur extra costs if necessary to keep contract outcome within the cost envelope. Overruns were viewed by the contractors as acceptable as long as they did not break ceiling.

3. "Target costs of incentive contracts are higher than the target costs of CPFF contracts." [Ref. 1: p. 45]

Many studies that Kennedy reviewed supported the conclusion that the targets of incentive contracts are higher than other types. The targets of FPI contracts appear higher than CPIF. In the 1960s, incentive contract underruns were due to inflated targets, whereas in the 1970s, increases in program definition and competition for scarcer defense dollars produced tighter targets and subsequent overruns. The general conclusion is that competition, tight funding, and good program definition can often drive the target down too low and result in overruns.

4. "The most significant factor in determining target cost for negotiation is where the company expects to end up." [Ref. 1: p. 52]

This effect varies with the economy and financial health of the firm. In the long run, the defense firm attempts to maintain an adequate profit (approximately 4-8%) [Refs. 2,3], increase its technology base, maintain good reputation, secure follow on business, and avoid the risk of loss. Therefore, the target negotiated will depend on such factors as the economy, DOD budgetary situation, excess capacity of the firm, and chances for follow on business, to name a few.

5. "The government's administration of the contract destroys any opportunity for the incentive to work." [Ref. 1: p. 69]

The higher the level of competition, the more likely that an incentive contract will overrun due to buying in, overoptimistic targets, or the attractiveness of the program in regards to technological development or follow on business. Government involvement blurs responsibility for poor contract outcome. Kennedy concludes that the administration of government procurement and policy is both cumbersome and counterproductive, in some cases - destructive.

6. "The cost of administering an incentive may outweigh any savings that might be achieved through the incentive arrangement." [Ref. 1: p. 78]

The administration costs of an incentive contract is excessive, and is a function of the complexity of the incentive(s). If an incentive is to work properly, it must be simple and have a minimum amount of administration applied to it.

7. "Many contractual arrangements are designed for intentional overruns." [Ref. 1: p. 86]

Buying-in, overoptimistic targets costs, or planning for slight overruns are common when competition is tight, funding is constrained, or the program has changes of generating a significant level of future business. Multiple incentives can protect a company from loss by allowing a negotiated structure that optimizes expenditures, since successful contracts are considered as those ending up below ceiling. Contractors will negotiate the contract to minimize their risk of loss, and contract structure is paramount to achieving this end. For example, a contractor can negotiate a tight target cost, a high target profit, and a low sharing rate, with an aim towards foregoing a few percentage points of profit to cover the probable overrun that will occur. The most important goal is to avoid losses while clearing a satisfactory profit level in the long run.

8. "Many incentive contracts are inappropriately structured." [Ref. 1: p. 108]

In general, there is a lack of situational tailoring in incentive contract design. The common practice is simply to pull from the book and apply with rules of thumb. Extra contractual factors are key, but usually ignored. The upper limits set on profit make it more attractive to incur costs not reduce them. A competitive environment results in risky target costs, and makes cost savings unlikely. Fee ranges have been too narrow, and risks have outweighed gains. Slopes of incentive share lines have been too shallow. Many government contracting and

acquisition people do not understand incentive structures or the implication of the combinations of ranges, fees, and share ratios. Often, too many elements are incentivized in the same contract. Rarely is there a clear relationship between the goals of the customer and the incentive structure.

9. "Penalties are better motivators than rewards." [Ref. 1: p. 120]

By structuring incentives correctly, a contractor can be motivated to reduce or control costs. The more likely that a contract will overrun, the more effective penalties will be. Nevertheless, if the intent of the incentive contract is to harness the profit motive as a positive incentive, then penalties are inconsistent with the framework. Penalties are already present in risk. For example, an FPI contract has both the greatest profit incentive and also the greatest penalty, if it is significantly overrun. Penalties if applied are much more appropriate for cost type contracts.

10. "The more complex the incentive arrangement, the more likely it will be ignored." [Ref. 1: p. 131]

Incentives must be simple to be effective. Many companies do not even implement simple incentives, much less worry about complicated ones. Relationships between parameters should be straightforward and target cost should be attainable. In summary, incentive contracts are difficult to construct and manage, especially in a competitive environment. The major attraction of incentive contracts, as they have generally been designed, to defense companies are the hidden "give away" aspects

that the government negotiators miss, or the minimizing of risk through negotiation of advantageous incentive parameters.

11. "The most important element in the incentive is performance." [Ref. 1: p. 143]

Performance incentives are not needed since companies will always achieve performance goals. Contractors will slip cost first, then schedule, but rarely performance. The motivation to maintain a flow of government business through good product reputation makes performance incentives unnecessary.

12. "Incentives have to have organizational visibility to work." [Ref. 1: p. 1-145]

Though results are inconsistent, the research shows that some degree of visibility is a must. However, the practice is rarely seen. The larger, more important programs are more likely to result in incentives flowing down through the contractor's organization. Most companies concentrate on their project budget, and let the incentives take care of themselves. As the major function of cost incentives is to discourage cost overruns, outcomes within the cost envelope (i.e., within ceiling) are seen as acceptable and therefore managed in the aggregate.

13. "CPIF contracts are fundamentally the same as CPFF." [Ref. 1: p. I-178]

CPIF contracts are not significantly more effective in controlling costs than CPFF. Though CPIF arrangements exhibit better communication between the government and the contractor, as well as better program definition, both CPFF and CPIF exhibit high targets. CPIF contracts encourage the contractor to expend

dollars and shift overhead and personnel charges among contracts. Since CPIF contracts provide significant risk protection, it encourages buying in. Unless very carefully structured and administered, the CPIF contract becomes the same as a CPFF type.

14. "Cost type contracts result in inefficient high cost producers." [Ref. 1: p. I-192]

The general conclusion reached in many studies is that cost contracts do not lead to cost efficiency. High quality may be there, but at exorbitant cost. Incentive type cost contracts do seem to foster better program definition, management, and communication, but at no savings to the government.

C. THE PILOT STUDIES

The pilot studies of two corporations [Ref. 1: p. II-4-13] provided continued validation of the previous findings. The important points of emphasis were:

1. The incentive contract must be structured with the organization in mind, especially the accounting and financial management systems. There is no sense in applying an incentive if the company is incapable of managing it.

2. The incentive arrangement succeeds or fails at the negotiation table.

3. Changes in general ruin the structure of an incentive contract. As the number of changes increase with the length of performance, the less effective are the incentives originally applied.

D. MAJOR FINDINGS OF SINGLE STUDIES

The Kennedy study gives a nutshell encapsulation of the important common findings in the incentive contracting literature. This base of knowledge can be further refined

however, with the addition of a few specific findings in the studies reviewed that are also important to the incentive design.

Dixon [Ref. 4] did a statistical study of NAVAIR FPI contracts in the 1949-65 timeframe and discovered some interesting relationships.

Deviations from target cost had an overall mean of -1.3 with a standard deviation of 9.1. This indicated that the NAVAIR FPI contracts, on the average, underran their targets by a little over 1%, with 68% (1 standard deviation to either side of the mean) falling in a range of 10.4% under target to 7.8% over target.

The deviations from target varied directly with the length of performance at 1.5% per year, supporting earlier conclusions that contracts of longer duration have greater chances of overrunning their targets.

Targets deviations also varied directly with profit at 1% per percentage increase over 9%. This tends to support the conclusion that high negotiated profits on incentive contracts indicate expected overruns by the contractor.

Another direct variation was noted between target deviations and ceiling price, at a rate of .4 per percentage increase over 123.2. This again supports earlier conclusions that, along with high negotiated profits, high negotiated price ceilings also indicate expected overruns.

Finally, target deviations varied indirectly with the number of contracts signed within a given year about the mean of 17 with a standard deviation of 8. The conclusion here was that the relationship represented a level of competition, indicating that the more or less intense the competition (i.e., outside the range of 9-26 contracts) the more significant the deviations from target.

These findings are not surprising. The relationships observed bear out the fact that contractors negotiate high profit to tight targets to cover planned overruns, and high ceilings to protect against loss when overruns are probable. Tight targets are negotiated when competition is intense or funding is tight, loose targets when competition and funding are less of a factor.

Scherer [Ref. 5] noted much of this back in 1964 when he characterized the competitive tight targets as "competitive optimism." He also noted that if a large number of contractors are bidding on a system, there is a lower probability of success, and therefore not as much money or effort is put into the proposal, rendering it less accurate in estimating costs. He also noted that there is a proclivity to "buy in" on developmental programs, since any losses that may occur can be made up on the follow on production contract. Scherer also noted that CPIF contracts are not much better than CPFF contracts, as they typically overrun by 15-20%. With FPI contracts, there was a near normal distribution of over/under runs, with an average underrun of 2.25% and a standard deviation of 10%. These are

virtually the same findings that Dixon came up with. Additionally, the data studied yielded a range of 77.75-117.75% of target for all incentive contracts with a confidence interval of 95%. This is important to note, as typical ceiling prices tend to fall in the range of 120-125%, slightly higher than the upper bound of actual outcomes observed.

Scherer also noted that the greater the bias toward underrun, the higher the contractor share, whereas the weaker the underrun bias, the higher the price ceiling. The general conclusion is that when uncertainty is great, low sharing proportions are the rule.

One very interesting item of note across the board in incentive contract studies is that the bulk of the sharing proportions studied are between 0-30%. Proportionately few incentive arrangements exist in the data base that are steeper than that. Though the bulk of the research concludes that incentive contracts as a whole are ineffective, perhaps the underlying reason may be that sharing ratios have been too shallow.

As further proof along these lines, Fisher [Ref. 6], in his reappraisal of incentive contracts, discovered that those few higher share ratios (over 30%) that he studied showed a marked decrease in target overruns as compared to the less steep share functions. (Table 2-1) Parker [Ref. 7] additionally noted that those share ratios greater than 30% did not generally result in

TABLE 2-1

MEAN OVER/UNDER RUN AND STANDARD DEV
AS A PERCENTAGE OF FINAL COST

ITEM	SHARING RATE VALUE			
	.01-.09	.10-.19	.20-.29	.30-.99
MEAN	1.45	-3.5	-2.32	-0.39
STANDARD DEV	12.95	13.86	8.45	8.81
NUMBER	43	144	156	87

higher profits than the less steep arrangements. Steeper share ratios may be one solution to the problem of making incentive contracts more effective.

One final significant study to mention is that of Jones [Ref. 8] on the differing degrees of commodity risk (Table 2-2) and their effect on incentive contract performance. He noted that different commodities in the defense market had different degrees of cost risk associated with them, differing amounts of changes, and different performance results to target. He also noted that the distribution, similar to Scherer's findings, were nearly normal, though not symmetrical about the mean, with a slight tendency to underrun. (Fig. 2-1) High risk groups had patterns that underran targets, low risk groups tended to overrun their targets.

E. SUMMARY

From the significant amount of literature reviewed in the area of incentive contracts and contractor motivation, some broad conclusions can be stated with reasonable assurance. One is that contractors as a group are more concerned with avoiding losses than making high profits, and see product quality as their primary contractual goal. Secondly, government application of cost incentives have been ineffective due to lack of integration with the contract, the contractor, and the environmental variables impacting the arrangement, thus rendering the incentive contract impotent as a tool to control costs.

TABLE 2-2

AVERAGE COST GROWTH AS A PERCENTAGE OF
COST GROWTH BY COMMODITY CLASS

CATAGORY	NBR OF CONTRACTS	AVERAGE CONTRACT MODS	AVERAGE OVER/UNDERRUN
AIRCRAFT	19	28.82%	22.11%
AIRCRAFT ENGINES	11	654.30%	1.82%
MISSLES	200	161.58%	-1.89%
COMBAT VEHICLES	65	296.58%	2.67%
NON-COMBAT VEHICLES	26	49.36%	-.48%
WEAPONS	32	91.80%	5.98%
AMMUNITION	118	53.41%	2.38%
ELECTRONICS	193	120.81%	13.10%
SERVICES	9	139.14%	10.41%
CONSTRUCTION	41	299.94%	10.17%
OTHER	27	94.28%	6.79%

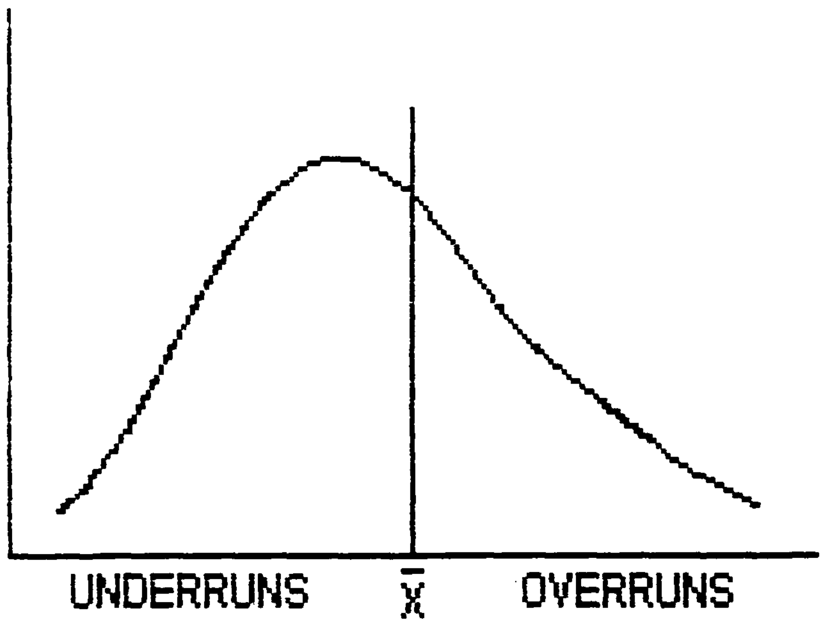


FIG. 2-1

Distribution of Incentive Contracts
Jones Study

Some of the more important facts to consider when designing an incentive arrangement are such items as:

- Final costs generally fall within 7-10% of target.
- Contractors look for approximately 4-8% profit in the long run.
- CPI contracts are little better than CPFF.
- Ceiling prices over 123%, and target profits over 9% indicate expected overruns by the contractor.
- Share rates greater than 30% appear to discourage cost growth.

The more important environmental factors to consider are:

- level of competition
- budgetary constraints
- state of the economy
- financial health of the contractor
- length of performance
- number of probable changes (maturity of system)
- commodity type
- financial/managerial system of contractor

Armed with these facts, the question is how to apply them in designing the effective incentive contract.

The first step is to consider the environmental variables and their probable impact on the behavior of the contractor, as well as the possibility that an incentive contract may not be applicable to the situation. For instance, if the level of competition is high, the economy in recession, the contractor is tight financially, and has a lot of excess capacity, a FFP

contract may be better to apply, as the likelihood of determining reasonable target costs are very slim. For another example, if the item being contracted for is in the high commodity risk group, and is a less mature system with a significant amount of changes likely under a long period of performance, an incentive contract again may not be applicable.

From the literature, some of the factors that appear to favor the application of incentive contracts are:

- a low to medium level of competition

- a more mature system with few expected changes (i.e., low commodity risk)

- a contractor who understands and can manage incentive structures

- good contractor financial health

- a reasonable level of free, but not excess, capacity

After making a determination of whether or not to apply an incentive arrangement, along with a consideration of the environmental factors and their probable impact on the arrangement, the design of the incentive structure itself is addressed. This is the most complicated process, for it is here that the negotiation position and strategy are formed, and upon which the success of the incentive rests.

Here, the validity of the target cost is crucial. Though statistically the final cost is likely to fall within 7-10% of the target, the target cost is supposed to represent the "expected cost," that cost which has equal probability of being either over or under run. Before any development of the incentive structure

begins, the cost elements of the contractor proposal must be studied carefully, and a cost risk analysis done to determine the most probable range where the target should fall. Within this range, the target cost must be established by integrating the relevant environmental factors previously discussed with their probable effects upon contractor behavior and motivation. This outcome must be further refined by a cost risk analysis, to arrive at a design which has the best chance of success. Available cost risk analysis techniques and their benefits are the subject of the following chapter.

III. COST RISK ANALYSIS

A. ANATOMY OF COST OVERRUNS

As the success of the cost incentive is usually based upon the final cost outcome, it is useful to discuss the nature of cost overruns prior to broaching the subject to risk.

In a recent Touche-Ross seminar [Ref. 9] on cost overruns in government contracting, held in San Francisco, CA in July 1985, the primary blame for cost overruns was attributed to poor cost estimating and management. Such items as inflation, inadequate specifications, out of scope work, delays, and changes, though important, were viewed as having a lesser impact overall.

Under the topic of cost estimating, the following six major areas were noted as problems:

1. General lack of understanding the request for proposal (RFP). This occurred either through the delivery of an inadequate RFP by the government, general lack of experience, or just plain carelessness.

2. Failure to properly apply historical data. This was due to poor estimating techniques, actual lack of data, obsolete data, using inappropriate data, or too rapid a preparation of the data and the estimate.

3. Overoptimistic estimates. Due to a general "can do" attitude, competitive pressure, desires to gain market share or break in to new technology, and a hope for recovery of any loss through follow on business or cost cutting later on.

4. Poor review of proposal by both the customer and the preparer. This was due to lack of objectivity, lack of skill, personal biases by reviewers, and tight time constraints.

5. Decentralized estimating. This often caused marginal instead of bottoms up costing, defective pricing, overoptimism, and lack of personal involvement of individual providing the costs with the final product.

6. Poor estimating team. Often the team was composed of accountants only, or comprised of those with a general lack of cost estimating skills. At times, no cost estimating team existed at all. Lastly, in those cases where a team operated as an established structured group, there was too much ego involvement by the various cost providers in their particular area.

In the area of management, the major problem areas addressed were:

1. Poor production control. Material was often not available, labor was not ready, and planning was disorganized.

2. Excess costs. Material costs were higher than predicted, often due to poor subcontracting and purchasing. Wrong scrap factors were used. Poor labor assignment and lack of proper training was evident. In some cases, insufficient labor was a problem. Lastly, high rework rates and a lack of understanding the application of the learning curve also contributed to problems in this area.

3. No chain of responsibility. In some cases, there was no program manager, resulting in poor budgeting and reporting of costs. Lack of foresight and timely problem solutions were also two major contributing factors in this area.

The minor areas mentioned (i.e., inflation, bad specifications, delays, etc.) were seen singly as items that were most often planned for as contingencies, and therefore were not critical.

In the attempt to avoid cost overruns, three stages of a project were focused on:

1. The proposal stage

2. The performance stage

3. Cost cutting

As the latter two stages deal mostly with management of the project post contract design and acceptance by both parties, they will not be specifically addressed here. However, the cost proposal stage is germane to the thrust of this report, and is the critical stage in overrun avoidance.

At the outset, a good estimating team of qualified personnel in each major area of work, who are familiar with standard estimating techniques, is a must. Secondly, any unclear points in the RFP must be fully clarified. Thirdly, members of the team must play the devil's advocate and continually address the "what ifs" in setting the probable cost estimates. Solutions for the possible problems that could arise must be planned for, and all assumptions defined and stated clearly with their attendant cost impact. The final numbers should be challenged by management and defended by team members. Last, but not least, different contract forms must be considered along with their impact on cost and bid contingencies, and one type chosen for a negotiating base.

This then provides an overall view from industry of the cost overrun situation and cost estimating as it relates to bid proposal. The emphasis on overrun avoidance is clearly set in the estimating and proposal stage. Work done properly here directly reduces chances of overrunning the contract. Cost estimation however, is not a pure science. It requires quite a bit of art in its application. It is only as accurate as the data applied, the technique used, the quality of the assumptions and the

measures of uncertainty and risk as determined by the estimator and proposal manager. The latter factor especially can make the difference between a successful estimate and proposal or an unsuccessful one, even with good data and technique.

What should be the expected accuracy of a good proposal estimate? Mr. Nathaniel Roosin, Chief Bid and Proposal Manager for Raytheon Corporation, who lectures extensively on cost estimating techniques, stated that it is difficult to compare actual costs with original proposal estimates and judge performance. [Ref. 10] At best, you attempt to adjust for changes that occurred over the life of the contract, and then try to arrive at a ballpark judgement on the quality of the estimate overall. As a rough yardstick, Mr. Roosin states that a good estimating team should be able to estimate actual costs within 10% over the long run across contracts. The researcher was left with an implication that this was an accuracy goal commonly sought in the industry.

Two important perspectives should be gleaned from this discussion. One is that government contracting personnel must be just as meticulous in the areas of cost estimation, RFP preparation, and proposal review as industry, and two, the common causal factors in the cost overrun situation should be kept in mind when reviewing the strengths and weaknesses of a proposal. Both sides must do their jobs properly to make the contract work. The necessity for understanding this process, and the reasonable cost accuracy that can be hoped for, and planned on, cannot be

understated. An approach to deal with cost estimation review and how to relate it with contract design is the next subject for discussion.

B A TECHNIQUE FOR COST-RISK ANALYSIS

By definition, target cost is that cost which has an equal probability (.5) of being either over or under run. [Ref. 11] The determination of target is therefore dependent upon risk. When speaking of risk in contracting, the three principle elements commonly referred to are: technical risk, schedule risk, and cost risk. Though the major element of interest here is cost risk, it must be emphasized that cost risk is not independent from the other two factors. The degree of possible interaction between the three should always be considered when assessing any one element.

To be more specific, the risk in each element can be defined as those random and uncontrollable factors, interacting with incomplete and uncertain knowledge, affecting the probability that an element in question will equal a predicted value. Risk is often illustrated by a probability distribution curve where, for example, cost would be on the y axis with associated probabilities from 0 to 100 appearing on the x axis. The expected cost is therefore that cost on the distribution which has the highest probability of occurrence (i.e., the modal value). The cost value that splits the distribution evenly is the median (50% of the curve to either side), and the average value is the

mean. In a normal distribution, the mean, median, and mode are all equal. In non-normal distributions, the target cost, by its definition, would be the median value. The variability of probable cost values is also important in determining contract structure, as the more variable a cost element, the higher the risk that it will be greater or less than the expected value.

For cost risk, total cost can be broken down into component parts such as labor, material, and overhead. Those parts can also be further subdivided into areas of engineering and production. In major systems acquisition, cost is broken down into work packages in a work breakdown structure (WBS) network, so that costs can be separately estimated, and then aggregated into a total. This is called the engineering or "bottoms up" approach to cost estimating. In theory, the further one can break down that total cost into individually analyzable units, the more accurate the estimate will be. The level of breakdown desired depends on two principle factors: the level of randomness of the item cost, and its effect upon total cost.

For example, many costs can be considered as nonrandom, such as those negotiated in a forward pricing rate agreement (principally overhead). Particular wage rates can also be nonrandom, though hours assigned may not. Additionally, some routine and recurring labor charges can be considered as nonrandom. As far as effect upon total cost, some highly variable elements may have significant impact upon the total cost, whereas others have very little. Suffice to say, the estimating effort

should focus on those costs exhibiting the greatest degree of variability with the greater impact on total cost.

Depending upon the time available for analysis, cutoff points can be established for those costs that will be analyzed in depth. For example, cost elements that exhibit variability enough to impact total cost less than 1-2% may be factored out to allow more time for the greater cost concerns. The appropriate cutoff point must be determined by the analyst.

An important concept to keep in mind though is that there are substantially more small risk items in a contract proposal than large ones. To ignore the small ones safely, they must be independent from one another. If any relationships exist, the sum total of their effects could add up to a major concern. When aggregating many independent elements however, small elements tend to cancel each other out statistically. Naturally this situation increases the need for complete and unbiased cost figures. In discussing this matter, Anderson [Ref. 12] notes that defense contractors as a group have often failed to make allowance for such items as rework and program planning in their proposal. It is therefore incumbent on the proposal reviewer to ensure not only that the costs are unbiased, but that all relevant cost elements are addressed.

Once the selected cost elements are established, ranges of possible cost swings must be determined to arrive at the probability distribution of possible costs about the expected value. A well performed bottoms up approach is critical in

reducing the variability of the total cost, and providing a firm foundation upon which to determine final contract structure. If a contractor has faith in his estimating organization, and has worked the proposal well, then his base cost should have some stated accuracy, or range of uncertainty. As discussed previously, management would like to have the base accurate to within 10% of future adjusted actuals. However, this is totally dependent upon the variability of the separate cost elements involved. Management will therefore add contingency dollars to those areas where risk exposure is the greatest, taking care not to add too much, resulting in a non-competitive bid. Nevertheless, the reviewer does not know where the contingencies are in the cost proposal, and it is precisely this information that is most needed to design an incentive related to risk and cost. One would logically expect that most cost contingencies will fall in those elements that have the greater variability, and thus the higher risk.

One simple analysis that can be performed to define the probable range and variability of cost is the utilization of the Beta distribution technique often applied in Pert and Pert cost networks. Though a fully developed Pert Cost network from the WBS would be ideal, it is too complicated and time consuming a process to do routinely in proposal validation; however, the method is sufficiently flexible to adapt to a more general cost risk analysis.

For this analysis, a technique used by George Worm, PhD, of Clemson University [Ref. 13] is used by the researcher as a tool upon which to base the development of the incentive structure discussed later in this report. Three figures are needed in this analysis:

1. a low cost value representing the best possible achievable cost under the most favorable of circumstances (.01 - .10 probability)

2. the most likely cost - the value used as the target cost (.5 probability)

3. a high cost value representing the highest possible cost given that most everything that can go wrong will. (.90 - .99 probability)

In Figure 3-1, a generalized Beta distribution is shown that is reflective of the research findings of cost outcomes to target for incentive contracts. Immediately one can see a problem with the construction as proposed so far. The most likely cost is a modal value, that falls on the underrun side of the distribution. The mean, as well as the median, fall at other different points along the curve. Which point should be chosen as the target cost? By definition, the median would be the choice as it is the cost that has the equal probability of being over or under run, having equal distribution of outcomes to either side. Intuitively of course, this would not make sense, as use of the median would produce continual underruns. The solution to this problem will be discussed later, after further development of the method at hand.

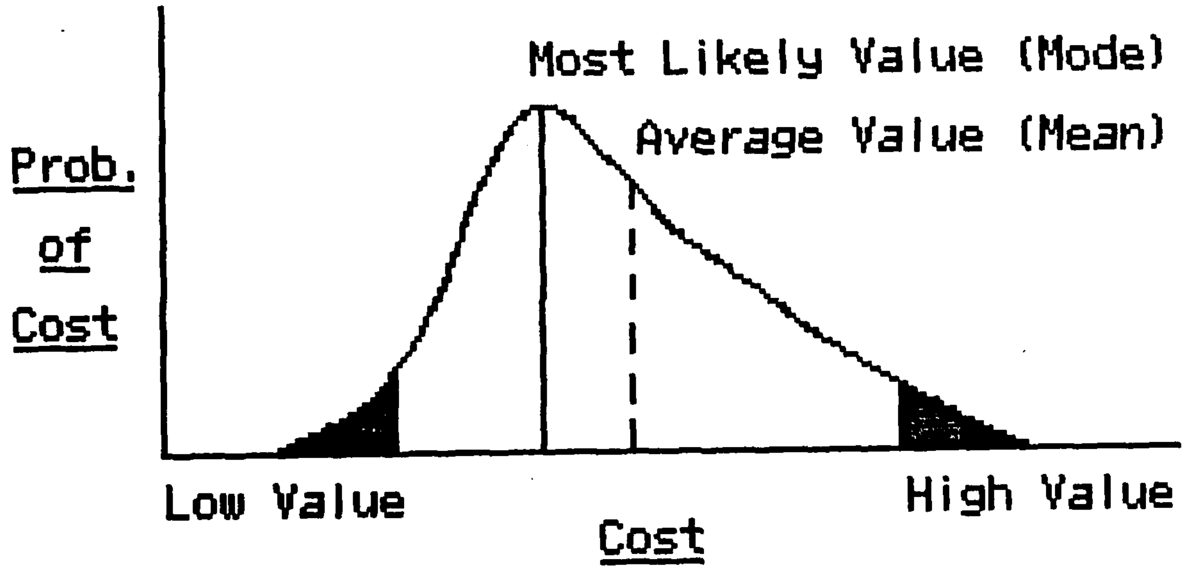


Fig 3-1 Beta Distribution

The determination of the above values should be based upon reasonable data and the judgement of both contractor cost estimators as well as government estimators in each cost area. Data focused on should include a fully worked and clarified contractor proposal complete with independent government estimates and cost audit analyses, past track record of estimates from the same company, and estimating trends in the industry for the same or similar products. The latter point is extremely important for, as Jones [Ref. 14] discovered, different commodities have differing cost and risk characteristics that should be considered in contract design in regards to the variability of the target cost negotiated.

All data should be analyzed from the standpoint of how tight the probable range to the estimated cost is. For example, has the contractor estimated costs well in the past, and has he a good data base from which to estimate this particular product? How has the industry as a whole done in estimating costs for the product in question? How wide is the cost contention between government and contractor cost estimates? If the company has good past data on the product, has estimated well in the past, industry estimating accuracy for the product has been acceptable, and the cost contention is minimal, then validation of the estimate is fairly straightforward. However, if many of the above factors are not so favorable, than a more rigorous analysis must be done to determine the probable target and its variability. Just how to break down the total cost for separate

analysis is a matter of judgement and time availabiilty. The target cost goal is one that most closely represents a .5 probability with some stated variability.

Technical experts as well as financial and accounting experts are needed in each broad area to establish cost ranges. Judgements of cost ranges need to be objective and reasonably backed up by the source queried. If an expert has a bias for or against a particular cost item or project, this will tend to bias the judgement. Of the acceptable values given by reasonable experts in each area, the maximum, minimum, and the most likely costs are established for a statistical manipulation in determining target and range.

The mechanics of the mathematical analysis described here are fairly straightforward, and can be performed on a calculator. A computer program to accomplish the analysis though, has been written by Dr. George Worm. The program was originally written in Fortran, however the researcher has translated it into BASIC and included the listing as well as the worksheets in Appendix A. A sample run on a set of representative data is included for illustrative purposes.

Before concentrating on the technique itself though, it is necessary to address the statistical foundation upon which it is based, specifically the applicability of the Beta distribution and its associated manipulation of data.

The Beta distribution [Ref. 15] is a class of continuous distributions where the probability of a given event is treated

as a random variable. The Beta has two parameters, r - the number of times an event occurs, and N - the total number of observations. The random variable p has the range of 0 -1. The distributions that result given various values of r and N take on an infinite variety of shapes. The most common Beta distributions illustrated are:

$r = N/2$ symmetrical curve

$r < N/2$ positive skew from normal

$r > N/2$ negative skew from normal

For the purpose here, if sample results are available, but p is not known, the Beta is very useful in estimating the distribution of p given r events observed in N trails. Especially when estimating in a diffuse state, i.e., where there is either very little prior information, or when the present sample information overwhelms prior knowledge, the Beta becomes one of the few methods that yields consistent results of acceptable accuracy. [Ref. 16]

For instance, Hays and Winkler [Ref. 17] describe the scenario of a person trying to determine the distribution of the weight of a potato handed to them. Given the size and shape of the potato in hand, and having some prior experience with potatoes, a person could derive a fairly accurate estimation of the probability distribution of weights for the potato. However, a person knows that the possible range of weight variability for potatoes in general is extremely wide, therefore the sample in hand tends to overwhelm any reliance upon prior knowledge, and

the distribution can best be described by a lowest possible weight, a highest possible weight, and a most likely weight or fairly tight range of likely weights in between.

When dealing with contract estimates, the situation is much the same. The contract in hand is a sample from all contracts whose cost outcomes have wide variability. The particular contract in question however has certain characteristics, type of commodity, contractor, dollar value, etc. that overwhelm prior information to the degree that the distribution of final cost is tight relative to the total N distribution. A reasonable distribution of probable cost can therefore be derived using the same method of determining the lowest, highest, and most likely cost.

The two values of the most interest in the Beta analysis are the mean and the variance of the cost distribution based upon the above three values. The figures to apply are those rigorously defined in the data gathering and proposal validation process for each cost element.

The formulae used to approximate the Beta values are:

Expected Value = (L + 4ML + H)/6

Variance = ((H - L)/6)^2

where:

L = lowest possible value

ML = most likely value

H = highest possible value

These calculations are performed for each element analyzed. The totals, including overhead and G & A burdens relative to the possible ranges, are summed for each separate element to derive the most likely values and variances. When aggregated in total, the result is a most likely total cost figure, with an associated variance range. Though this will be discussed further in Chapter IV, interested readers should review Ref. 13 for a more in depth discussion of this approach.

This technique for cost risk analysis is simple, effective, and not overly time consuming as compared to other methodologies, including exact calculation of the Beta values. Yet it can provide a foundation for developing a good incentive design based on risk. Three points must be kept in mind however:

1. As with any statistical methodology, bad data will yield poor results. Care must be taken to insure that data used in validating the proposal as well as the proposal data itself, are accurate, complete, and applicable.

2. Contractor inefficiencies in performance or cost control are not expressely considered in this technique. As envisioned by Dr. Worm, it is to consider uncertain environmental factors only, with reasonable expectations of contractor responsibility. He recommends that any doubts as to contractor performance in this area should be addressed in the weighted guidelines, and not in added costs to allow for the possibility within the technique itself. However, the researcher feels that is a significant history of data reveals certain propensities in one direction or another for either a contractor, or a particular commodity, then there should be no reason why they should not be part of the relevant cost ranges. The final decision must be left to the analyst, and his tolerance for wider cost ranges by inclusion of these factors.

3. Lastly, the crucial point of independence between cost elements can not be understated. If several cost elements are dominated by another element or factor, the sum of the maximum cost estimate of each related element may be better

than the final risk analysis cost as determined by the Beta method. Aggregation of related costs into one element is perhaps the best approach for dependent costs where feasible.

C. SUMMARY

The researcher has now presented the common characteristics of incentive contracts as revealed by the research literature, and has discussed the concept of risk as it applies to the element of cost. Using the information presented up to this point, it is now time to illustrate how to integrate this broad framework into the design of the incentive contract, with an eye towards refining its application, and improving its effectiveness.

IV. COST INCENTIVE DESIGN

A. TRADITIONAL APPLICATION OF THE COST INCENTIVE

The common types of incentive contracts used for cost control are: fixed price incentive (FPI), cost plus incentive (CPI), and award fee (CPAF, FPAF). In the latter case, the structure of the contract does not use a fixed incentive or sharing arrangement, and therefore is not germane to this report. As previously discussed in Chapter II, research strongly supports the conclusion that CPI contracts do no better at controlling costs than their fixed fee (CPFF) counterparts, and thus the researcher will ignor their application as well. This then leaves the FPI contract design as the one representative structure acceptable to use as the example to contrast with the research approach to follow.

In reviewing briefly the basic design and structure of the FPIF contract [Ref. 18], it is helpful to view the incentive as being applied to a set level of performance and schedule values that remain constant in the contract. This is opposed to a multiple incentive design, where many contract parameters can vary and be incentivized.

The overall incentive design requires that cost, technical, and schedule risk be reasonably identified, and that the share ratio be consistent with the degree of uncertainty present. Thus the major concerns of the contract designer, as noted in Chapter

III, are the definition of the areas of uncertainty, the relevant cost range, and the associated probabilities of occurrence. This requires both good program definition as well as good cost estimates, based upon adequate performance and design specifications. These estimates must be validated before selecting the probable target cost to be negotiated. Actual cost can reasonably be expected to deviate from whatever target is finally negotiated. Thus the design of the cost incentive must deal primarily with the variance of the total cost, and provide for a sharing function that covers the most probable range where the final cost will fall. This range of probable cost outcome of which the sharing incentive is applied is called the range of incentive effectiveness (RIE). Through this range is applied a linear sharing function of the type y=mx + b. The actual function can be expressed as:

Profit = .X(Target Cost - Actual Code) + Target Profit

where X is the contractor's share percentage

The general design can be depicted graphically as in Figure 4-1, where a typical 80/20 cost incentive share line is shown. The value of X in our profit formula in this case is 20. The government's share value is the numerator of the share ratio, and the denominator the contractor's. In simple terms the incentive displayed provides the contractor with 20% more profit, or 20 cents on the dollar, for every dollar saved under the cost target. The same factor applies as a reduction to target profit for every dollar over the cost target. On the other side of the

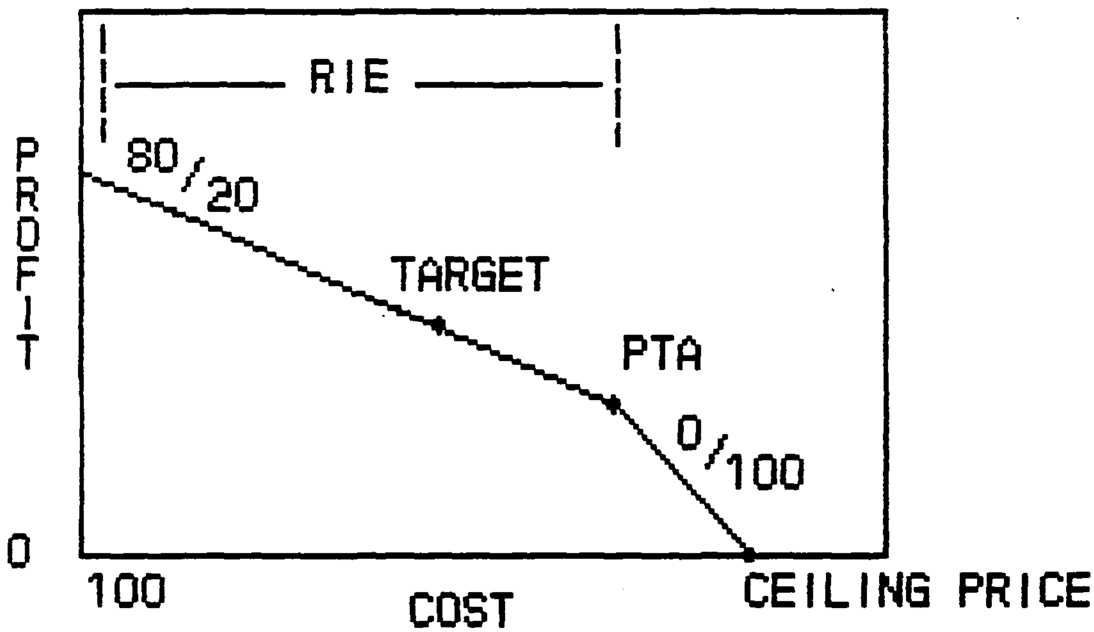


Fig. 4-1 Typical FPIF Design

coin, the government shares 80%, or 80 cents on the dollar, for costs saved, and incurs extra cost at the same rate for any costs incurred over the target.

The other points to address in Figure 4-1 are the PTA (point of total assumption), the ceiling price, and the RIE (range of incentive effectiveness) which was mentioned previously. The PTA is the maximum point in the RIE where sharing ceases and the contractor absorbs 100% of any further costs incurred. The share line continues beyond this point however at essentially a 0/100 share slope until it reaches zero on the profit axis. This point is referred to as the ceiling price, and is the maximum total dollars that the government will pay the contractor. Costs incurred beyond this point represent a loss. The other end of the share line extends to zero on the cost axis, which is the low point of the RIE. Even though the lowest probable cost is far above that point, based on good estimates of cost and variance, profit ceilings are generally not established, thereby maximizing motivation at that end of the cost range.

Share ratios can take on many different values in negotiation depending upon how the cost variance, and the reasonableness of the targets (cost and profit), are perceived by both sides. As mentioned in the research reviewed in Chapter II however, most share ratios historically have fallen at and above the 70/30 level. One finds very few arrangements below that, for example 50/50, though more recent observations would indicate a movement in that direction.

Additionally, the share ratio need not be regular throughout the RIE, but can change linearly at certain points as shown in Figure 4-2. Here, there is a relatively flat slope about the target, with a steeper share line being applied below the target than above the target. This particular arrangement comes the closest in intent to the researcher's approach in applying incentive sharing functions.

The primary reasons why one would want to apply such an arrangement are not immediately obvious. There is a small range of cost deviation around the target which is completely unpredictable even with the best estimates. Why then should we reward or penalize the contractor to any significant degree within this area? As mentioned in Chapter III, industry cost estimators strive for an estimate that they feel is accurate within 10% (plus or minus). This, for example may be an area best left relatively flat in the incentive design. Furthermore, since we want to provide strong motivation for cost control, the incentive share is greater for costs under target. To reduce the contractors risk of loss, a less steep sharing ratio is applied to the overrun side of target. Although this makes good intuitive sense, in practice it can be very cumbersome and extremely difficult to negotiate.

However, the fact remains that when setting share rates, the variance of the cost target as well as the probabilities of those variances occurring, must be assessed to establish a proper RIE, target cost, and target profit. This is critical in motivating

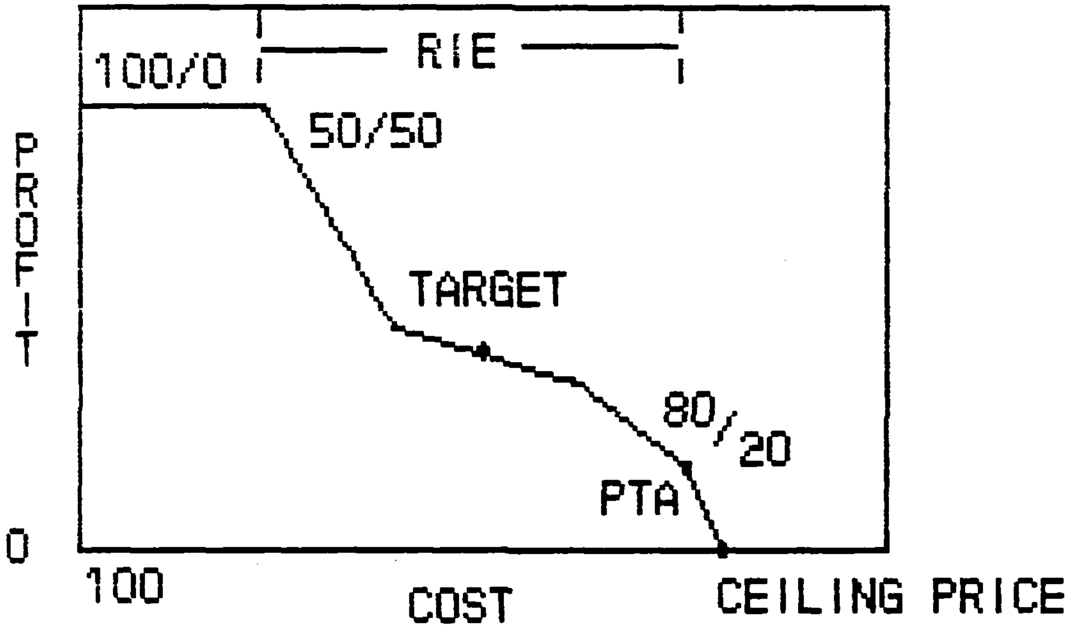


Fig. 4-2 FPIF with Broken Share Line

the contractor to control costs yet not impact negatively on the technical performance, schedule, or the effectiveness of the incentive itself. In other words, cost must not be overemphasized at the expense of the other contract objectives.

These guidelines are the prime reason wny incentive contracts require the characteristics mentioned in Chapter II, particularly relatively stable design, with fewer expected changes than the norm. This stability is part of good program definition leading to reliable cost estimates to work from. Lacking this, it is impossible to realistically set proper targets and share ratios that will be relatively free from contractor gaming during the negotiation process, which often renders the resulting incentive impotent. If the contractor is hungry for business, facing stiff competition in his market, and has a lot of excess capacity, the problem will be even harder to avoid. Target cost in his proposal may already be too low to effectively incentivize. This again, harkens back to Chapter II in its discussion about understanding the environment that the contract is being negotiated in. This understanding guides the choice of proper contract type, and the design of a proper incentive, if that avenue is chosen.

Upon completion of the research on the contractor, the commodity, the overall contractual environment, and the validity of the cost estimates, the RIE, cost/profit targets, and the share ratio need to be determined. The question remaining is how best can cost risk be applied in the overall design? We have seen how

the mechanics of the basic linear share function works in the FPI contract, now the research approach can be described for comparison.

B. THE RESEARCH APPROACH

The design of the cost incentive should reflect the cost risk inherent in the contract. Risk however, changes as time and conditions surrounding the contract change. The linear share function reflects a constant risk condition across the probable cost range of RIE, except in cases where the share line slope changes at various points as discussed previously. Though this latter approach has some merit, it is difficult to design due to the lack of a well supported methodology to arrive at the proper shift points. This adds additional burdens to the regular task of negotiating the cost/ profit target, and RIE itself.

The basic problem then is one of arriving at a sound standard methodology for applying risk in some systematic fashion to the design of the RIE and share function. The researcher has done this by using a curve in place of a linear share function, where the share ratio changes as a function of the cost variance.

The approach involves the application of two basic statistical precepts, the Empirical Rule, and Variance. [Ref. 19] The researcher simply calculated the standard deviation by taking the square root of the cost variance figure, such as the one derived from the Worm method described in Chapter III. The Empirical Rule states that in a normal distribution, 1 standard

deviation plus or minus from the mean will cover 68% of probable outcomes, 2 standard deviations 95% of outcomes, and 3 standard deviations nearly all outcomes. (Fig. 4-3)

The researcher chose a range of two standard deviations from the target as the RIE. In recalling the Beta method of calculating the most likely target cost described in Chapter II, the resultant value represents an approximation to the mean of the distribution. It is important at this point to clarify two issues in this respect. The research, as discussed in Chapter II, suggests that the distribution of actual costs to target can be generalized by the Beta distribution shown in Figure 3-1, as opposed to the normal upon which the Empirical Rule is based. However, the research generally supports the conclusion that this situation stems from poor contract design and application of the incentive, leading to inflated targets. The researcher feels that proper contract application and design would signifiantly reduce the difference between the modal and mean value as seen in the research. By definition, target cost has equal probability of being over or under run. This is actually a definition of the median. In a normal distribution the mean median, and mode are all equal. The researcher feels that the actual difference that exists is acceptable for estimation purposes, and thus the application of the Empirical Rule is a sound one. Furthermore, the Worm method of calculating target and variance based upon the Beta remains acceptable as well, since it also applies for a Beta where r=N/2, a symmetrical distribution that includes the normal,

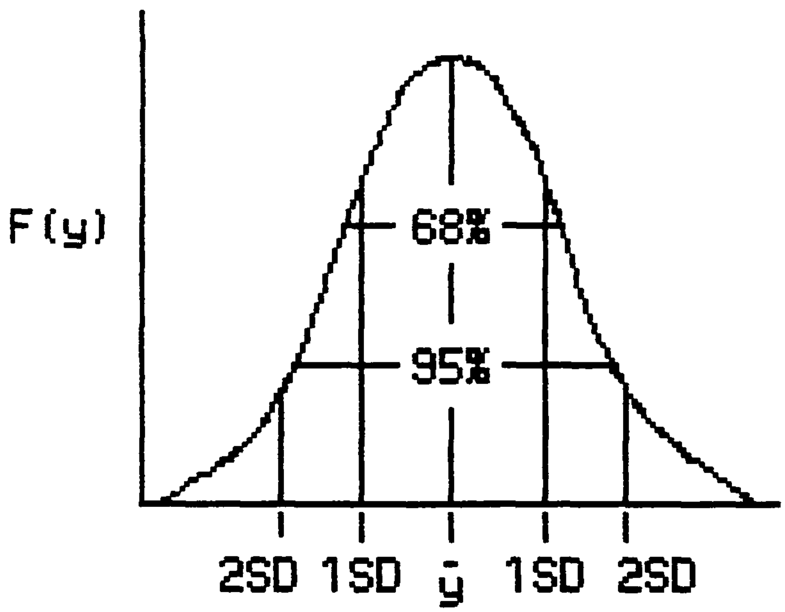


Fig. 4-3 Normal Distribution

as mentioned in Chapter III. A second issue is the researcher's choice of a wider range for the RIE (95% of probable outcomes) than is generally allowed by published guidance [Ref. 18: pp. 81-87]. The standard has been to restrict the range to the most probable cost outcomes rather than a broader coverage. The researcher feels however, that to make the incentive effective, the RIE should have as wide a range as possible to provide for maximum motivation. The range that the reseracher has established also defines the low and high point of the RIE, where the low cost point represents a profit ceiling and the high cost point represents the PTA, with PTA equaling ceiling price.

Now that the RIE has been established, the share function is calculated by modifying the linear profit equation as follows:

$$\text{Profit} = TP \pm \left(\frac{|AC - TC|}{2 \times SD}\right)^2 \times TP$$

$$\lim TC \pm 2 \times SD$$

where AC = Actual Cost TC = Target Cost

TP = Target Profit SD = Standard Deviation of Cost

The squared factor times Target Profit is added to Target Profit for costs below target, and subtracted from Target Profit for costs above target. The function results in a curve of cost/profit points that reflect cost risk as a function of the standard deviation of a probable cost outcome from the target.

The researcher has written a program in BASIC that calculates the share curve based upon this formula, prints out specific cost/profit points at intervals specified by the user, and displays rough cost versus profit and price versus cost graphs

for comparison purposes. Examples of program runs using cost targets of differing variability, with differing target profits, are shown in Appendix B.

As seen in the output, the share function yields a slow rate of profit share changes about the target, with the rate of change increasing as the standard deviation of the probable cost outcomes increase. This provides for less contractor risk within a reasonable range of target, with strong motivators for cost control by increasing the rate at which the share is applied as the cost deviation increases. As the RIE covers 95% of the probable cost outcomes, the share curve automatically adjusts to the higher risk involved when the probable cost variance is large. Well defined targets, with small associated variances, will see tighter RIEs with share curves displaying steeper rates of change. In the opposite case, the RIE will be wider, and the rate of share change more gradual.

This method could have two important advantages in actual practice:

1. It is systematic and based upon acceptable statistical parameters. It therefore removes a great deal of arbitrariness and guesswork in establishing the RIE and the share function.

2. If accepted by the contractor, it could significantly reduce the time spent in negotiation.

The primary disadvantages are that the method is complex, not so much in computation, but in concept, and the increased risk sharing by the government cuts across the grain of much current policy.

C. THE RELATIONSHIP OF TARGET PROFIT, CONTRACT PRICE, AND COST VARIANCE

This application leaves one element left for negotiation, the target profit. It is the only factor that is not systematically calculated based upon statistical or risk based methodologies. This is necessary since this input will largely determine the strength of the incentive as reflected in the share curve. The prime influences with which to provide positive motivation are: the sharing or reduction of contractor risk, and the level of profit as the reward for cost efficiency. As seen from the research in Chapter II, indications are that often high target profits, with low sharing rates and high cost ceilings, represent an offset for expected overruns when target costs were perceived as too risky. Notice that in the researcher's approach, target profit doubles at the minimum point and zeros out as the maximum point of the RIE. Both of these extremes only occur at a probability level of .05. Though some may take exception with profit levels that have the possibility of doubling, the approach here concentrates on final price to the government, and views profit as a secondary consideration. To provide for effective levels of motivation, the contractor must be able to attain high profit levels for associated high levels of cost efficiency. If we allow the contractor 10% of target cost as profit for example, we must recognize that the capability of earning 20%, even though the possibility of attaining it is low, would provide a strong incentive. Even if that level is actually reached, the

government would receive a bargain as far as final price compared to target is concerned. The level of profit per se should not be an overriding concern.

Upon a simple visual examination of Figure 4-4, where a representative linear function is overlaid on its associated share curve (i.e., as if it were fit by regression), it is easily seen without integrating the respective functions that the area under the curves are nearly equal. The implication here is that the government would be exposing itself to little if any additional cost exposure, over the total range of the function, by applying the curved as opposed to a linear share design.

In order to fully understand the properties of the curvilinear function however, two other relationships need to be studied. One is the relationship of price to cost, and the other is the relationship between profit and cost variance.

Since the profit/cost graph is automatically scaled to the input parameters, all the output curves look the same, only the scale and relevant values change. It is therefore much more useful to view a price/cost graph to get a better view of what is happening. In Appendix B, four price/cost graphs are shown using a constant target cost figure of 500, and a base profit figure of 10%, while varying the standard deviation of cost at 5%, 8%, 10%, and 20%. As can be observed from the graphs, the function changes the price to cost relationship significantly as the cost variance changes. Essentially, if we begin at a 0% standard deviation of cost, the price/cost graph would be flat. At 5%, the

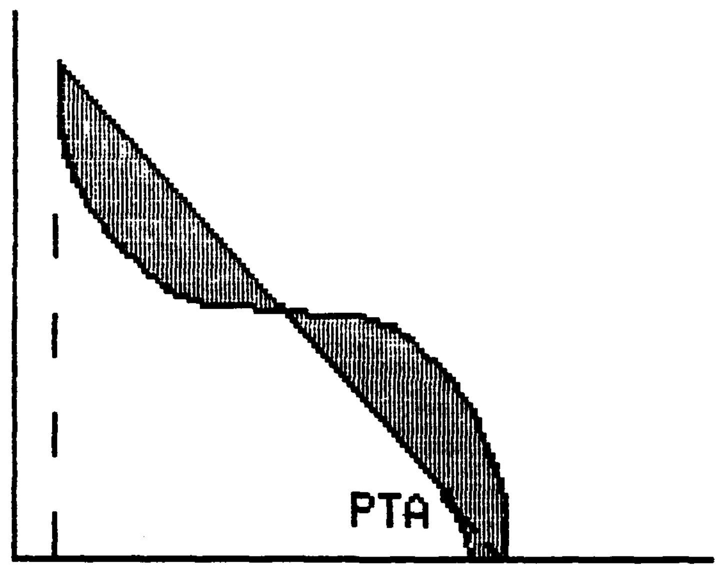


Fig. 4-4 Area under Curves
Linear vs Curved Share Lines

curve shows an S shaped bend from the flat line. It is interesting to note in this case that target cost, and the maximum/minimum points on the curve are all equal. It is certain that a contractor would prefer a firm fixed price arrangement over this sharing function at such low cost variances. The 8% cost variance shows a continuing trend towards elongation of the S shape, and also displays a contractual arrangement that nearly turns into a firm fixed price arrangement past 1 standard deviation of cost. The 10% graph continues the trend, flattening out rapidly at the 1 standard deviation point. The final graph of a 20% standard deviation of cost simply stretches out the curve more. From 10% on, no other significant changes occur, the graph is merely stretched out with a more gradual slope, depicting a contract price that increases at a decreasing rate as cost increases.

The researcher concludes that this observed trend would not lend itself to actual application of the curved share function much below a 10% standard deviation of cost. A contractor would more likely prefer a firm fixed price arrangement rather than accept the function's properties below that variance level. Coincidentally, the break point conforms quite nicely with the statement referred to earlier in this report by Mr. Roosin, that contractors would like their estimates accurate to within 10% of actuals. Given that management has this assurance, one could expect firm fixed price contractual desires, as their risk is relatively small. Beyond 10% of cost, risk of loss rises

rapidly, principally because normal profit margins can more readily be exhausted. The price/cost graph indicates that beyond 10%, the curve pattern does not change much, but increases at a decreasing rate with cost. This provides for a high level of risk sharing within 1 standard deviation above target, and strong motivation for cost control at or beyond 1 standard deviation.

Recalling Figure 4-4, where a comparative linear share line was overlaid on the curve, the areas under both curves would actually only be equal if the PTA and the ceiling price were equal. Though this does not occur in the standard FPIF design, this is indeed the case over nearly all of the functional applications of the research approach. In studying Table 4-1, a matrix has been provided to compare different cost variances with different profit levels. The cells are divided in half, with the top portion showing the respective linear function as applied in Figure 4-4, while the lower half of the cell shows where the PTA falls. In nearly all cases, PTA equals ceiling price. The only case where it does not are in those cases where there is high profit applied to low cost variability, which would not actually be seen in reality.

An interesting trend is noted on the diagonals of the matrix, where the cost variance figures are equal to the profit levels. In each case, the linear share comparison has a 50/50 split. Furthermore, where cost variance is twice the profit percentage, the associated linear sharing function is 75/25. In summary, the two trends to key on are that when profit is held constant, the

TABLE 4-1
COMPARATIVE LINEAR SHARE RATIOS
AND PTAS

S.D. AS A % OF COST	5%	7.5%	10%	12.5%	15%	CEILING PRICE
5%	50/50	25/75	0/100	0/125	0/150	
	XX	XX	500	500	500	550
10%	75/25	63/37	50/50	37/63	25/75	
	XX	XX	XX	XX	XX	600
15%	83/17	75/25	67/33	58/42	50/50	
	XX	XX	XX	XX	XX	650
20%	87/13	81/19	75/25	69/31	63/37	
	XX	XX	XX	XX	XX	700

PROFIT

XX-PTA=C.P.

government portion of the share tends to increase as the variance increases. When variance is held constant, the government linear share comparison decreases as profit increases. This relationship makes logical sense, however, it must be kept in mind that the share curve does not really equate to these linear comparisons. They are only the closest correlaries with which to compare the curve's properties.

In fact, though the areas under the curves are equal across both the linear and curved functions, the widest difference occurs at 1 standard deviation above and below the target. On the underrun side, the government share is less than the linear comparison, while on the overrun side it is more. The difference of course rapidly approaches the linear comparison as it slopes away from the 1 standard deviation point. What does this suggest?

The researcher concludes that the curve could immediately benefit the government with the observed tendencies for inflated targets and slight underruns, as the final cost would be less than a comparative linear share on the underrun side. Of course, this is based on the assumption that the curved function would be used directly in place of the linear function as currently applied. Since the curved function is developed primarily upon the estimated cost variance, this is not likely to be the case. In looking at the overall goals of the approach however, that of strengthening the motivation for cost control by increasing the profit possibilities while providing increased sharing of risks, the function appears to achieve these goals.

Risk for the contractor is greatest at 1 standard deviation of cost, when cost variance is greater than the profit level. It is at this point that losses occur. Recalling that 68% of all outcomes in a normal distribution fall within plus or minus 1 standard deviation, this is where the likely outcomes will fall. Beyond 1 standard deviation are the less likely outcomes. If the contractor has prepared his estimates well, manages the contract properly, and the government does not negatively impact the process, then the outcome should be within 1 standard deviation. Outside of this are those areas of extraordinary foul ups on the overrun side, or extraordinary efforts at cost reduction or increases productivity on the underrun side.

What is desired is some measure of increased cost sharing where the contractor is most vulnerable. This would reduce inflated targets and gaming to avoid loss, and thus provide a better environment for the profit motive to take effect. On the underrun side, the government should not provide much additional profit for mediocre cost control, or for costs saved only because targets were inflated. The government desires significant improvements in cost control and increased productivity, and should be ready to provide strong incentives to do so. The researcher believes that close scrutiny of the curved share approach will show that it indeed does this. The matrix shown in Table 4-1 additionally implies that the government shares less in

the risk at higher cost variances when the profit levels are also high. This should provide much food for thought in comparing this type of approach to current methods.

V. SUMMARY

A. GENERAL CONCLUSIONS

The purpose of this research was to examine the incentive contracting experience as illustrated by the literature base, and integrate relevant cost risk analysis techniques into the design of the incentive contract in a manner better reflecting the cost risk involved. The focus centered on the linear share function, contrasting it with an alternative method which applied a share curve based on cost variance. The researcher feels that this approach better reflects cost risk in the design of the incentive and thus provide more motivational impact.

The primary research question was whether or not the standard methods of incentive contact design, using linear share functions, are optimal in motivating contractors to cost efficiency given the respective cost risk involved. The researcher found that the literature base strongly supported the conclusion that historically incentive contracts have been poorly designed and subject to a great deal of gaming by contractors during negotiation. The result has been impotent incentives, and a general dismissal by the professional community of the past effectiveness of the instrument as a whole. Thus the researcher concludes that though standard methods appear not be optimal in effectively motivating contractor cost performance, the fault may not entirely lie with the concept of the linear share application, but with poor design

and application of the instrument itself. However, even given proper application of the standard cost incentive, after all relevant data has been applied (i.e., contractor/commodity research, proper validation of cost estimates, assessment of current contracting environment, etc.), this researcher feels that the design would still not be optimal. The linear share function is a static design that does not change as risk changes along the distribution of probable cost outcomes.

The subsidiary research questions involved cost risk analysis, and its application to the share function. The researcher concluded that the important factors to consider is assessing the cost risk were:

- contractor characteristics such as overall financial health, market position, and level of excess capacity.
- commodity characteristics such as stability of design, quality of program definition, past quality of industry cost estimates, and past history of the propensity for changes.
- environmental characteristics such as current budgetary, market/economic, and regulatory pressures impacting the contract.
- validity of cost estimates judged by past experience, quality and completeness of data, and level of disparity between government and contractor estimates.

The question of how to quantify some of these factors involved using techniques, such as the Worm method, that can be used to systematically establish most likely cost values and respective variances. The researcher chose the statistical concept of variance to quantify risk through the application of the standard deviation of cost from target. The share function

was then bent into a curve by utilizing a formula that increased the sharing rate as the standard deviation of cost from target increased.

The researcher believes that cost variance reflects risk in that the larger the cost variance, the greater the cost risk. Since the share curve adapts itself automatically as cost variance increases or decreases, the researcher feels that it is a better alternative than the linear approach in compensating for the cost risk. Furthermore, the improvement in design should more effectively motivate contractors towards cost efficiency.

The last point considered was that the share curve's motivational effectiveness, perhaps even more than the standard linear approach, depends heavily upon the target profit negotiated. The researcher feels that too much emphasis is placed on profit levels as a percentage of cost. The concern should be on final cost to the government. Thus, though the contractor could conceivably double his negotiated target profit by extraordinary (.05 probability) cost efficiency, the cost savings to the government would be worth the high reward. If optimal motivation is to be achieved under this researcher's approach, the contractor must not only be given the opportunity to earn high profits when highly efficient performance in cost control is achieved, but also have his "risk averse" tendencies mitigated by greater risk sharing. Only then will the profit motive operate to produce cost efficient behavior.

APPENDIX A: THE WORM TECHNIQUE

```
10 DIM A(8,5),ETC(5)
20 REM REAL MOR, MWR, MGOR
30 PRINT "THIS PROGRAM WAS WRITTEN TO PERFORM THE NECESSARY"
40 PRINT "CALCULATIONS FOR A RISK ANALYSIS BY GOERGE WORM, 1980"
50 PRINT "THE LINES REQUIRING THREE INPUTS END WITH L, ML, H"
60 PRINT
70 PRINT "MATERIAL COST L, ML, H"
80 INPUT A(1,1), A(1,2), A(1,3)
90 PRINT
100 PRINT "MATERIAL OVERHEAD INDEPENDENT L, ML, H"
110 INPUT A(2,1), A(2,2), A (2,3)
120 PRINT
130 PRINT "MATERIAL OVERHEAD RATE %"
140 INPUT MOR
150 MOR=MOR/100
160 PRINT
170 PRINT "INTERDIVISIONAL TRANSFERS L, ML, H"
180 INPUT A(3,1), A(3,2), A(3,3)
190 PRINT
200 PRINT "DIRECT ENGR LABOR (HOURS OR COST) L, ML, H"
210 INPUT A(4,1), A(4,2), A(4,3)
220 PRINT
230 PRINT "ENGR WAGE RATE (ENTER 1 IF LABOR IS COST AND NOT HOURS)"
240 INPUT EWR
250 PRINT
260 PRINT "ENGR OVERHEAD INDEPENDENT L, ML, H"
270 INPUT A(5,1), A(5,2), A(5,3)
280 PRINT
290 PRINT "ENGR OVERHEAD RATE %"
300 INPUT EOR
310 EOR=EOR/100
320 PRINT
330 PRINT "DIRECT MFG LABOR (HOURS OR COST) L, ML, H"
340 INPUT A(6,1), A(6,2), A(6,3)
350 PRINT
360 PRINT "MFG WAGE RATE (ENTER 1 IF LABOR IN COST AND NOT HOURS)"
370 INPUT MWR
380 PRINT
390 PRINT "MFG OVERHEAD INDEPENDENT L, ML, H"
400 INPUT A(7,1), A(7,2), A(7,3)
410 PRINT
420 PRINT "MFG OVERHEAD RATE %"
430 INPUT MGOR
440 MGOR=MGOR/100
450 PRINT
460 PRINT "OTHER COSTS L, ML, H"
470 INPUT A(8,1), A(8,2), A(8,3)
480 PRINT
490 PRINT "G&A EXPENSE (PERCENT OF SUBTOTAL) %"
500 INPUT GAE
```

```
510 GAE=GAE/100
520 PRINT
530 FOR I=1 TO 8
540   A(I,4)=(A(I,1)+4*A(I,2)+A(I,3))/6
550   A(I,5)=((A(I,3)-A(I,1))/6)^2
560 NEXT I
570 FOR I= 1 TO 4
580   ETC(I)=(1+MOR)*A(1,I)+A(2,I)+A(3,I)+EWR*(1+EOR)*A(4,I)+A(5,I)
590   ETC(I)=ETC(I)+MWR*(1+MGOR)*A(6,I)+A(7,I)+A(8,I)
600   ETC(I)=ETC(I)*(1+GAE)
610 NEXT I
620 ETC(5)=(1+MOR)^2*A(1,5)+A(2,5)+A(3,5)+(EWR+EWR*EOR)^2*A(4,5)
630 ETC(5)=ETC(5)+A(5,5)+(MWR+MWR*MGOR)^2*A(6,5)+A(7,5)+A(8,5)
640 TSL=ETC(4)+3*SQR(ETC(5))
650 RATIO=3*SQR(ETC(5))/ETC(4)
660 IF (RATIO > .05) GOTO 710
670 PRINT "SINCE VARIABILITY IS SMALL FFP IS RECOMMENDED"
680 TP=0
690 CR=0
700 GOTO 760
710 PRINT "SINCE VARIABILITY IS MORE THAN 5% FPIF IS RECOMMENDED)"
720 RATIO=RATIO*100
730 PRINT "EXPECTED TOTAL COST = "; ETC(4)
740 PRINT "INPUT WGM PROFIT (PERCENT)"
750 INPUT TP
760 TP=TP/100
770 PRINT "RISK ANALYSIS UPPER LIMIT = "; TSL
780 PRINT "INPUT COST RISK USED IN WGM (PERCENT)"
790 INPUT CR
800 CR=CR/100
810 PRINT TAB(20) "ESTIMATES FOR RISK ANALYSIS"
820 PRINT
830 PRINT
840 PRINT TAB(2)"ELEMENTS"
850 PRINT TAB(44)"MOST"
860 PRINT TAB(30)"MINIMUM        LIKELY         MAXIMUM"
870 PRINT
880 PRINT "MATERIAL","COST",A(1,1),A(1,2),A(1,3)
890 PRINT "MGT OVERHEAD","INDEPENDENT   ";A(2,1),A(2,2),A(2,3)
900 PRINT      "  RATE FOR MATERIAL  ";MOR
910 PRINT "INTERDIV TRANSFERS   COST  ",A(3,1),A(3,2),A(3,3)
920 PRINT "DIRECT ENGR LABOR   HOURS  ",A(4,1),A(4,2),A(4,3)
930 PRINT TAB(2)"WAGE RATE";" ";EWR
940 PRINT "ENGR OVERHEAD - INDEPENDENT ";A(5,1),A(5,2),A(5,3)
950 PRINT TAB(2)"RATE FOR ENGR";" ";EOR
960 PRINT "DIRECT MFG LABOR   HOURS  ",A(6,1),A(6,2),A(6,3)
970 PRINT TAB(2)"WAGE RATE";" ";MWR
980 PRINT "MFG OVERHEAD - INDEPENDENT  ";A(7,1),A(7,2),A(7,3)
990 PRINT TAB(2)"RATE FOR MFG";" ";MGOR
1000 PRINT "OTHER COST","COST  ",A(8,1),A(8,2),A(8,3)
```

```
1000 PRINT "OTHER COST","COST   ",A(8,1),A(8,2),A(8,3)
1010 PRINT "G&A EXPENSE";" ";GAE
1020 PRINT
1030 PRINT TAB(20)"SUMMARY, CEILING/SHARE COMPUTATION"
1040 PRINT
1050 PRINT
1060 PRINT "SUMMARY, MINIMUM COST",ETC(1)
1070 PRINT "SUMMARY, MOST LIKELY COST",ETC(2)
1080 PRINT "SUMMARY, MAXIMUM COST",ETC(3)
1090 PRINT "EXPECTED TOTAL COST, E(TC)",ETC(4);" EXCEEDED W/PROB=.5
1100 PRINT "RISK ANALYSIS COST, RAC",TSL;" EXCEEDED W/PROB<.01
1110 IF TP=0 GOTO 1300
1120 WP=TP-CR
1130 WPD=TSL*WP
1140 PRINT "WARRANTED PROFIT"TAB(29);WPD
1150 TPD=TP*ETC(4)
1160 PRINT "TARGET PROFIT"TAB(29);TPD
1170 CP=TSL+WPD
1180 PRINT "CEILING PRICE"TAB(29);CP
1190 PRINT
1200 PRINT "%TAGE DIFFERENCE BETWEEN RAC & OBJECTIVE",RATIO
1210 PRINT
1220 PRINT "SHARING COMPUTATION"
1230 DUMM=TPD-WPD
1240 PRINT "WGM PROFIT LESS WARRANTED PROFIT",DUMM
1250 DUM=TSL-ETC(4)
1260 PRINT "RISK ANALYSIS COST LESS OBJECTIVE COST",DUM
1270 CS=DUMM/DUM*100
1280 PRINT "CONTRACTORS SHARE",CS;"%"
1290 PRINT
1300 PRINT "DO YOU WISH TO CHANGE WGM PROFIT OR RISK?"
1310 PRINT "(TYPE 0 FOR YES, 1 FOR NO)"
1320 INPUT ANS
1330 IF ANS=0 GOTO 730
1340 END
```

ESTIMATES FOR RISK ANALYSIS

DATE ____________

ESTIMATES

SUBCOMPONENTS			MINIMUM (L)	MOST LIKELY (ML)	MAXIMUM (H)	EXPECTED VALUE $\frac{L + 4ML + H}{6}$	CALCULATED VARIANCE $\left(\frac{H - L}{6}\right)^2$
MATERIAL		COST				E(V1)	Var(V1)
MATERIAL OVERHEAD		INDEPENDENT				E(V2)	Var(V2)
RATE FOR MATERIAL	☐	P1					
INTERDIV TNSERS		COST				E(V3)	Var(V3)
DIRECT ENGRG LABOR		HOURS				E(V4)	Var(V4)
WAGE RATE	☐	R1					
ENGRG OVERHEAD		INDEPENDENT				E(V5)	Var(V5)
RATE FOR ENGRG	☐	P2					
DIRECT MFG LABOR		HOURS				E(V6)	Var(V6)
WAGE RATE	☐	R2					
MFG OVERHEAD		INDEPENDENT				E(V7)	Var(V7)
RATE FOR MFG	☐	P3					
OTHER COSTS		COST				E(V8)	Var(V8)
G&A EXPENSES							
PERCENT OF SUBTOTAL	☐	P4					

RISK ANALYSIS WORKSHEET (EXPECTED VALUE)

	(COL 1)		(COL 2)	(COL 3) = (COL 1) * (COL 2)
(1 + P1)	______	E(V1)	______	______
	1	E(V2)	______	______
	1	E(V3)	______	______
(R1 + R1*P2)	______	E(V4)	______	______
	1	E(V5)	______	______
(R2 + R2*P3)	______	E(V6)	______	______
	1	E(V7)	______	______
	1	E(V8)	______	______
			TOTAL (COL 3)	______
			(1 + P4)	______
			EXPECTED TOTAL COST = E(TC) = (1 + P4)* TOTAL (COL 3)	______

RISK ANALYSIS WORKSHEET (VARIANCE)

	(COL 1)		(COL 2)	(COL 3) = (COL 1) * (COL 2)
$(1 + P1)^2$	______	Var(V1)	______	______
	1	Var(V2)	______	______
	1	Var(V3)	______	______
$(R1 + R1 \cdot P2)^2$	______	Var(V4)	______	______
	1	Var(V5)	______	______
$(R2 + R2 \cdot P3)^2$	______	Var(V6)	______	______
	1	Var(V7)	______	______
	1	Var(V8)	______	______
			TOTAL (COL 3)	______
			$(1 + P4)^2$	______

VARIANCE OF TOTAL COST = Var(TC) = $(1 + P4)^2$ *TOTAL (COL 3) ______

```
RUN
THIS PROGRAM WAS WRITTEN TO PERFORM THE NECESSARY
CALCULATIONS FOR A RISK ANALYSIS BY GEORGE WORM, 1980
THE LINES REQUIRING THREE INPUTS END WITH L, ML, H

MATERIAL COST L, ML, H
? 11000,15000,22000

MATERIAL OVERHEAD INDEPENDENT L, ML, H
? 0,0,0

MATERIAL OVERHEAD RATE %
? 30

INTERDIVISIONAL TRANSFERS L, ML, H
? 50000,72000,100000

DIRECT ENGR LABOR (HOURS OR COST) L, ML, H
? 5000,6200,7800

ENGR WAGE RATE (ENTER 1 IF LABOR IS COST AND NOT HOURS)
? 22

ENGR OVERHEAD INDEPENDENT L, ML, H
? 0,0,0

ENGR OVERHEAD RATE %
? 80

DIRECT MFG LABOR (HOURS OR COST) L, ML, H
? 20000,28000,42000

MFG WAGE RATE (ENTER 1 IF LABOR IN COST AND NOT HOURS)
? 16

MFG OVERHEAD INDEPENDENT L, ML, H
? 0,0,0

MFG OVERHEAD RATE %
? 150

OTHER COSTS L, ML, H
? 500,680,1100

G&A EXPENSE (PERCENT OF SUBTOTAL) %
? 50

SINCE VARIABILITY IS MORE THAN 5% FPIF IS RECOMMENDED)
EXPECTED TOTAL COST =  2253045
INPUT WGM PROFIT (PERCENT)
? 10
RISK ANALYSIS UPPER LIMIT =  2697286
INPUT COST RISK USED IN WGM (PERCENT)
? 4
```

ESTIMATES FOR RISK ANALYSIS

ELEMENTS	MINIMUM	MOST LIKELY	MAXIMUM
MATERIAL COST	11000	15000	22000
MGT OVERHEAD INDEPENDENT	0	0	0
RATE FOR MATERIAL .3			
INTERDIV TRANSFERS COST	50000	72000	100000
DIRECT ENGR LABOR HOURS	5000	6200	7800
WAGE RATE 22			
ENGR OVERHEAD - INDEPENDENT	0	0	0
RATE FOR ENGR .8			
DIRECT MFG LABOR HOURS	20000	28000	42000
WAGE RATE 16			
MFG OVERHEAD - INDEPENDENT	0	0	0
RATE FOR MFG 1.5			
OTHER COST COST	500	680	1100
G&A EXPENSE .5			

SUMMARY, CEILING/SHARE COMPUTATION

```
SUMMARY, MINIMUM COST          1594200
SUMMARY, MOST LIKELY COST      2186550
SUMMARY, MAXIMUM COST          3177870
EXPECTED TOTAL COST, E(TC)     2253045  EXCEEDED W/PROB=.5
RISK ANALYSIS COST, RAC        2697286  EXCEEDED W/PROB<.01
WARRANTED PROFIT               161837.2
TARGET PROFIT                  225304.5
CEILING PRICE                  2859123

%TAGE DIFFERENCE BETWEEN RAC & OBJECTIVE   19.71735

SHARING COMPUTATION
WGM PROFIT LESS WARRANTED PROFIT           63467.35
RISK ANALYSIS COST LESS OBJECTIVE COST     444240.8
CONTRACTORS SHARE              14.2867 %

DO YOU WISH TO CHANGE WGM PROFIT OR RISK?
(TYPE 0 FOR YES, 1 FOR NO)
? 1
OK
```

APPENDIX B: THE RESEARCH TECHNIQUE

```
10 CLS
20 CLS:KEY OFF
30 PRINT "THIS PROGRAM CALCULATES AN INCENTIVE SHARE CURVE BASED UPON THE"
40 PRINT "STANDARD DEVIATION OF TOTAL COST, THE COST TARGET, AND TARGET"
50 PRINT "PROFIT. WHEN PROMPTED FOR VALUES, ENTER VALUES IN THREE TO FOUR"
60 PRINT "SIGNIFICANTY DIGITS FOR BEST RESULTS. EXAMPLE : 450 FOR 450,000"
70 PRINT "500 FOR 500 MILLION, AND SO ON. WHEN SELECTING INTERVALS, CHOOSE"
80 PRINT "INTERVALS THAT WILL GENERATE AT LEAST 10 POINTS TO PRODUCE THE"
90 PRINT "SMOOTHEST CURVE."
100 PRINT
110 PRINT "TO RUN THE PROGRAM, PRESS G"
120 INPUT R$
130 IF R$="G" THEN GOTO 140 ELSE IF R$="g" THEN GOTO 140 ELSE END
140 CLS
150 PRINT:PRINT:PRINT:PRINT:PRINT
160 INPUT "ENTER TARGET COST";TC
170 INPUT "ENTER TARGET PROFIT";TP
180 INPUT "ENTER STANDARD DEVIATION OF COST";SD
190 REM CALCULATE COST SWING
200 LRANGE=TC-(2*SD)
210 URANGE=TC+(2*SD)
220 INPUT "COST INTERVALS DESIRED";SCALE
230 CLS
240 REM NUMBER OF POINTS CALCULATED
250 GROUPS=(URANGE-LRANGE)/SCALE
260 REM GENERATE POINT CALCULATIONS
270 N=GROUPS/2
280 DIM FACTOR(100)
290 DIM X(100):DIM Y(100):DIM Z(100)
300 DIM T$(100)
310 FOR I=1 TO N
320 PRINT
330 PRINT
340 FACTOR(I)=((I*SCALE)/(2*SD))^2
350 NEXT I
360 PRINT "COST, PROFIT, AND PRICE POINTS"
370 PRINT
380 PRINT "COST","PROFIT",,"PRICE"
390 FOR I=N TO 1 STEP -1
400 PROFIT = TP+(FACTOR(I)*TP)
410 COST=TC-(I*SCALE)
420 PRICE = COST + PROFIT
430 IF FACTOR(I)=1 THEN PRINT COST,PROFIT,,PRICE:X(I)=COST:Y(I)=PROFIT:Z(I)=PRIC
E:GOTO 460
440 PRINT COST,PROFIT,,PRICE
450 X(I)=COST:Y(I)=PROFIT:Z(I)=PRICE
460 NEXT I
470 PRINT TC,TP, "TARGET",TC+TP
480 X(N+1)=TC:Y(N+1)=TP:Z(N+1)=TC+TP
490 FOR I=1 TO N
500 PROFIT = TP-(FACTOR(I)*TP)
```

```
510 COST=TC+(I*SCALE)
520 PRICE = COST + PROFIT
530 PRINT COST,PROFIT,,PRICE
540 X(I+N+1)=COST:Y(I+N+1)=PROFIT:Z(I+N+1)=PRICE
550 NEXT I
560 PRINT
570 REM COST AND PROFIT RANGES FOR GRAPH
580 X1=TC-3*SD
590 X2=TC+3*SD
600 Y1=0
610 Y2=(TP*2)+10
620 PRINT
630 PRINT "TO SEE GRAPH OF PROFIT VS COST, PRESS G":INPUT G$
640 IF G$="G" THEN GOTO 650 ELSE IF G$="g" THEN GOTO 650 ELSE GOTO 1410
650 CLS:SCREEN 2
660 SX=590/ABS(X2-X1)
670 SY=130/ABS(Y2-Y1)
680 XO=35
690 YO=140
700 LINE (35,YO)-(625,YO)
710 LINE (XO,10)-(XO,140)
720 LOCATE 19,4: PRINT X1
730 LOCATE 19,75: PRINT X2
740 IF GRAPH$="PRICE" THEN Y1=TC
750 IF GRAPH$="PRICE" AND SD/TC>.1 THEN Y1=Z(N)
760 LOCATE 18,1:PRINT Y1
770 DEFINT W
780 W=Y2/10
790 W=W*10
800 IF GRAPH$="PRICE" THEN W=Z(GROUPS+1)+TP
810 IF GRAPH$="PRICE" AND SD/TC>.1 THEN W=Z(GROUPS+1)
820 LOCATE 2,1:PRINT W
830 GX=SD:GY=10
840 IF SD/TC>.1 THEN GY=20
850 Y=YO-GY*SY
860 IF Y<10 GOTO 900
870 FOR X=35 TO 625 STEP 4:PSET (X,Y):NEXT X
880 Y=Y-GY*SY
890 GOTO 860
900 Y=YO+GY*SY
910 IF Y>140 GOTO 950
920 FOR X=35 TO 625 STEP 4:PSET (X,Y):NEXT X
930 Y=Y+GY+SY
940 GOTO 910
950 X=XO-GX*SX
960 IF X<35 GOTO 1000
970 FOR Y=10 TO 140 STEP 2:PSET (X,Y):NEXT Y
980 X=X-GX*SX
990 GOTO 960
1000 X=XO+GX*SX
```

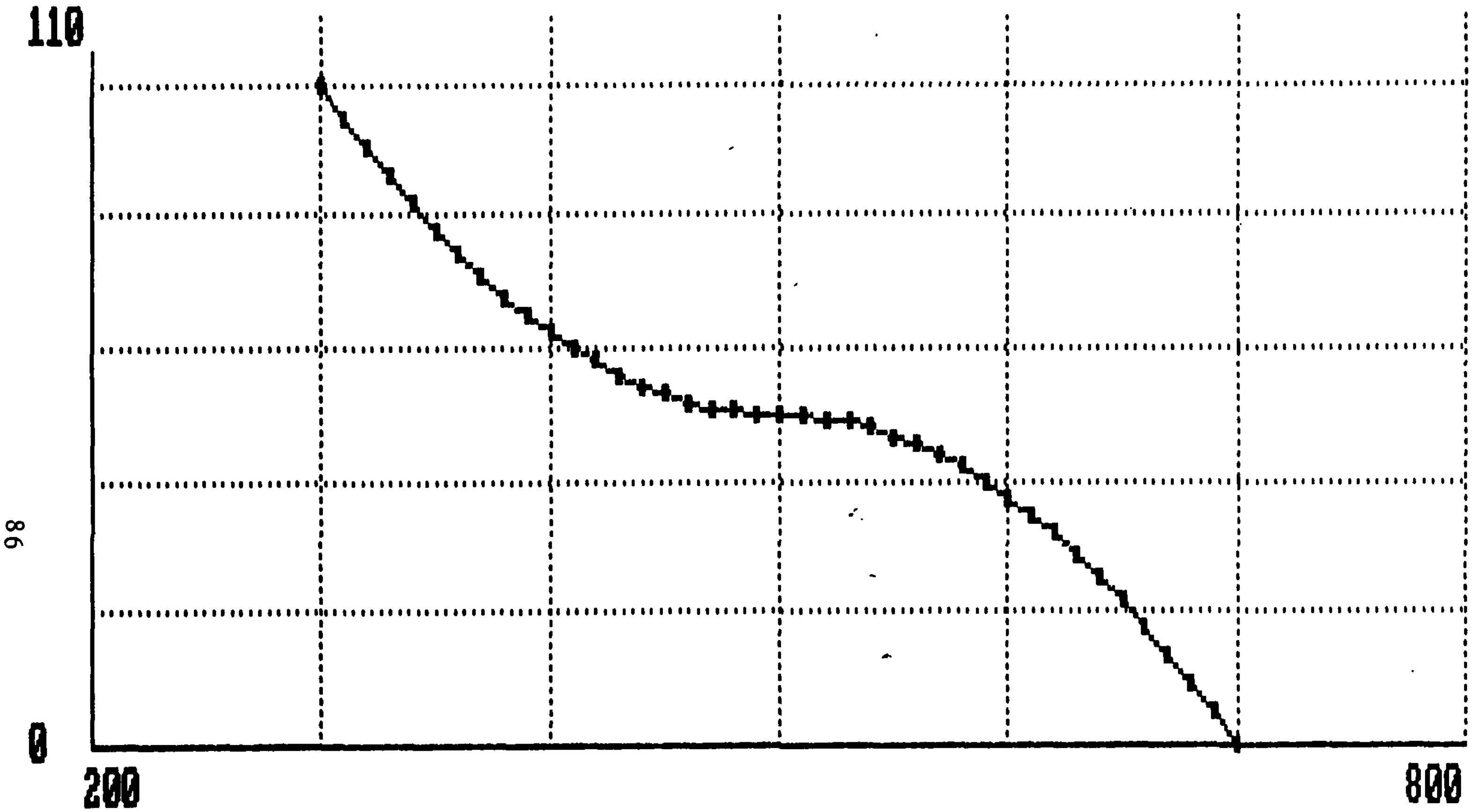
```
1010 IF X>625 GOTO 1050
1020 FOR Y=10 TO 140 STEP 2:PSET (X,Y):NEXT Y
1030 X=X+GX*SX
1040 GOTO 1010
1050 REM
1060 PT=GROUPS
1070 FOR I=1 TO (PT+1)
1080   A=XO+(X(I)-X1)*SX
1090 IF GRAPH$="PRICE" THEN Y(I)=Z(I)-Z(N)
1100   B=YO-Y(I)*SY
1110   LINE (A-1,B-1)-(A-1,B+1):LINE (A,B-1)-(A,B+1):LINE (A+1,B-1)-(A+1,B+1)
1120 NEXT I
1130 FOR J=1 TO (PT+1):T$(J)="N":NEXT J
1140 A=+999999!
1150 XS=-99999!
1160 FOR J=1 TO (PT+1)
1170 IF X(J)>=XS AND X(J)<A THEN A=X(J):P1=J
1180 NEXT J
1190 T$(P1)="Y"
1200 NC=1
1210 NC=NC+1
1220 IF NC>(PT+1) GOTO 1370
1230 A=+999999!
1240 FOR J=1 TO (PT+1)
1250 IF J=P1 GOTO 1270
1260 IF X(J)>=X(P1) AND X(J)<A AND T$(J)="N" THEN A=X(J):P2=J
1270 NEXT J
1280 IF P1=P2 GOTO 1390
1290 A=XO+(X(P1)-X1)*SX
1300 B=YO-Y(P1)*SY
1310 AA=XO+(X(P2)-X1)*SX
1320 BB=YO-Y(P2)*SY
1330 LINE (A,B)-(AA,BB)
1340 T$(P2)="Y"
1350 P1=P2
1360 GOTO 1210
1370 IF GRAPH$="PRICE" THEN GOTO 1380 ELSE GOTO 1390
1380 LOCATE 21,35:PRINT "PRICE VS COST":GOTO 1470
1390 LOCATE 21,32: PRINT "INCENTIVE SHARE CURVE":LOCATE 22,35:PRINT "PROFIT VS C
OST":PR=1
1400 IF GRAPH$="PRICE" AND PR=1 THEN GOTO 1470
1410 PRINT "TO SEE GRAPH OF PRICE VS COST PRESS G":INPUT G$
1420 IF G$="G" THEN GOTO 1440 ELSE GOTO 1430
1430 IF G$="g" THEN GOTO 1440 ELSE GOTO 1470
1440 GRAPH$="PRICE"
1450 IF SD/TC>.1 THEN Y2=Z(GROUPS+1)-TC+SD:GOTO 650
1460 Y2=Z(GROUPS+1)-TC+TP:GOTO 650
1470 PRINT "TO RUN THE PROGRAM AGAIN, PRESS G"
1480 INPUT R$
1490 IF R$="G" GOTO 1500 ELSE IF R$="g" THEN GOTO 1500 ELSE GOTO 1510
1500 CLEAR:GOTO 140
1510 END
```

```
? RUN
THIS PROGRAM CALCULATES AN INCENTIVE SHARE CURVE BASED UPON THE
STANDARD DEVIATION OF TOTAL COST, THE COST TARGET, AND TARGET
PROFIT. WHEN PROMPTED FOR VALUES, ENTER VALUES IN THREE TO FOUR
SIGNIFICANTY DIGITS FOR BEST RESULTS. EXAMPLE : 450 FOR 450,000
500 FOR 500 MILLION, AND SO ON. WHEN SELECTING INTERVALS, CHOOSE
INTERVALS THAT WILL GENERATE AT LEAST 10 POINTS TO PRODUCE THE
SMOOTHEST CURVE.

TO RUN THE PROGRAM, PRESS G
? G




ENTER TARGET COST? 500
ENTER TARGET PROFIT? 50
ENTER STANDARD DEVIATION OF COST? 100
COST INTERVALS DESIRED? 10
```

COST, PROFIT, AND PRICE POINTS

COST	PROFIT		PRICE
300	100		400
310	95.125		405.125
320	90.5		410.5
330	86.125		416.125
340	82		422
350	78.125		428.125
360	74.5		434.5
370	71.125		441.125
380	68		448
390	65.125		455.125
400	62.5		462.5
410	60.125		470.125
420	58		478
430	56.125		486.125
440	54.5		494.5
450	53.125		503.125
460	52		512
470	51.125		521.125
480	50.5		530.5
490	50.125		540.125
500	50	TARGET	550
510	49.875		559.875
520	49.5		569.5
530	48.875		578.875
540	48		588
550	46.875		596.875
560	45.5		605.5
570	43.875		613.875
580	42		622
590	39.875		629.875
600	37.5		637.5
610	34.875		644.875
620	32		652
630	28.875		658.875
640	25.5		665.5
650	21.875		671.875
660	18		678
670	13.875		683.875
680	9.500004		689.5
690	4.875		694.875
700	0		700

TO SEE GRAPH OF PROFIT VS COST, PRESS G
? G



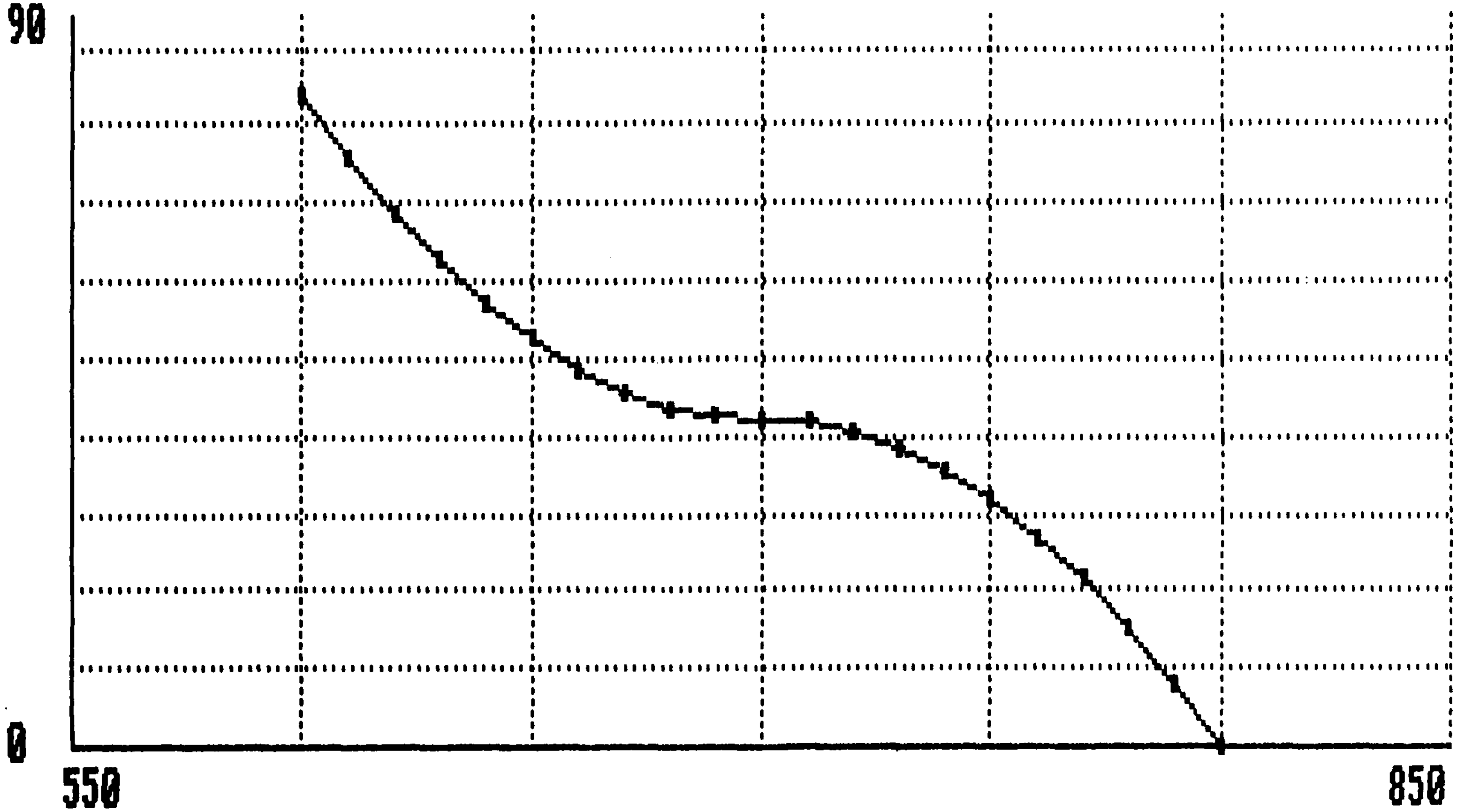
INCENTIVE SHARE CURVE
PROFIT VS COST

```
ENTER TARGET COST? 700
ENTER TARGET PROFIT? 42
ENTER STANDARD DEVIATION OF COST? 50
COST INTERVALS DESIRED? 10
```

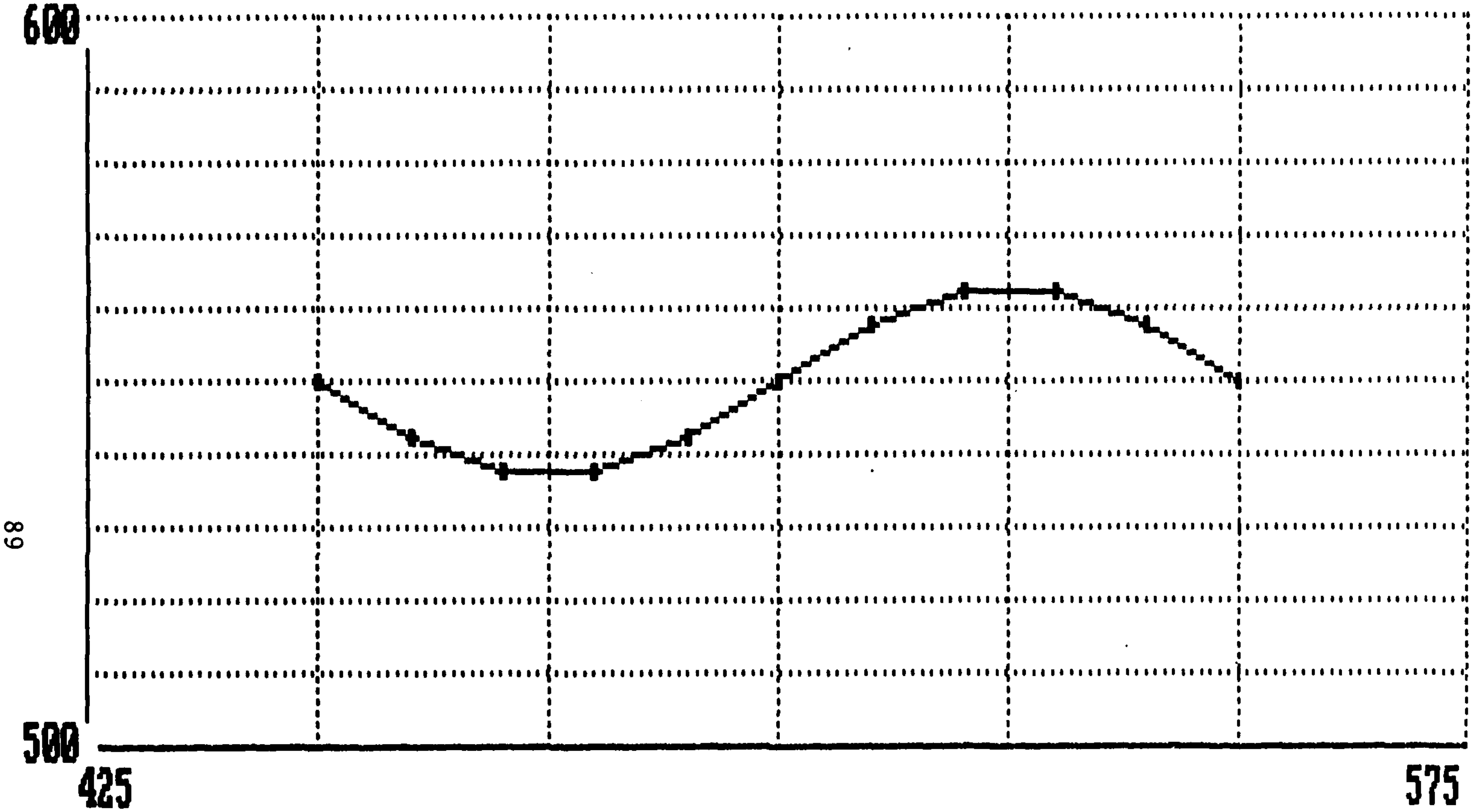
COST, PROFIT, AND PRICE POINTS

COST	PROFIT		PRICE
600	84		684
610	76.02		686.02
620	68.88		688.88
630	62.58		692.58
640	57.12001		697.12
650	52.5		702.5
660	48.72		708.72
670	45.78		715.78
680	43.68		723.68
690	42.42		732.42
700	42	TARGET	742
710	41.58		751.58
720	40.32		760.32
730	38.22		768.22
740	35.28		775.28
750	31.5		781.5
760	26.88		786.88
770	21.42		791.42
780	15.12		795.12
790	7.980004		797.98
800	0		800

TO SEE GRAPH OF PROFIT VS COST, PRESS G

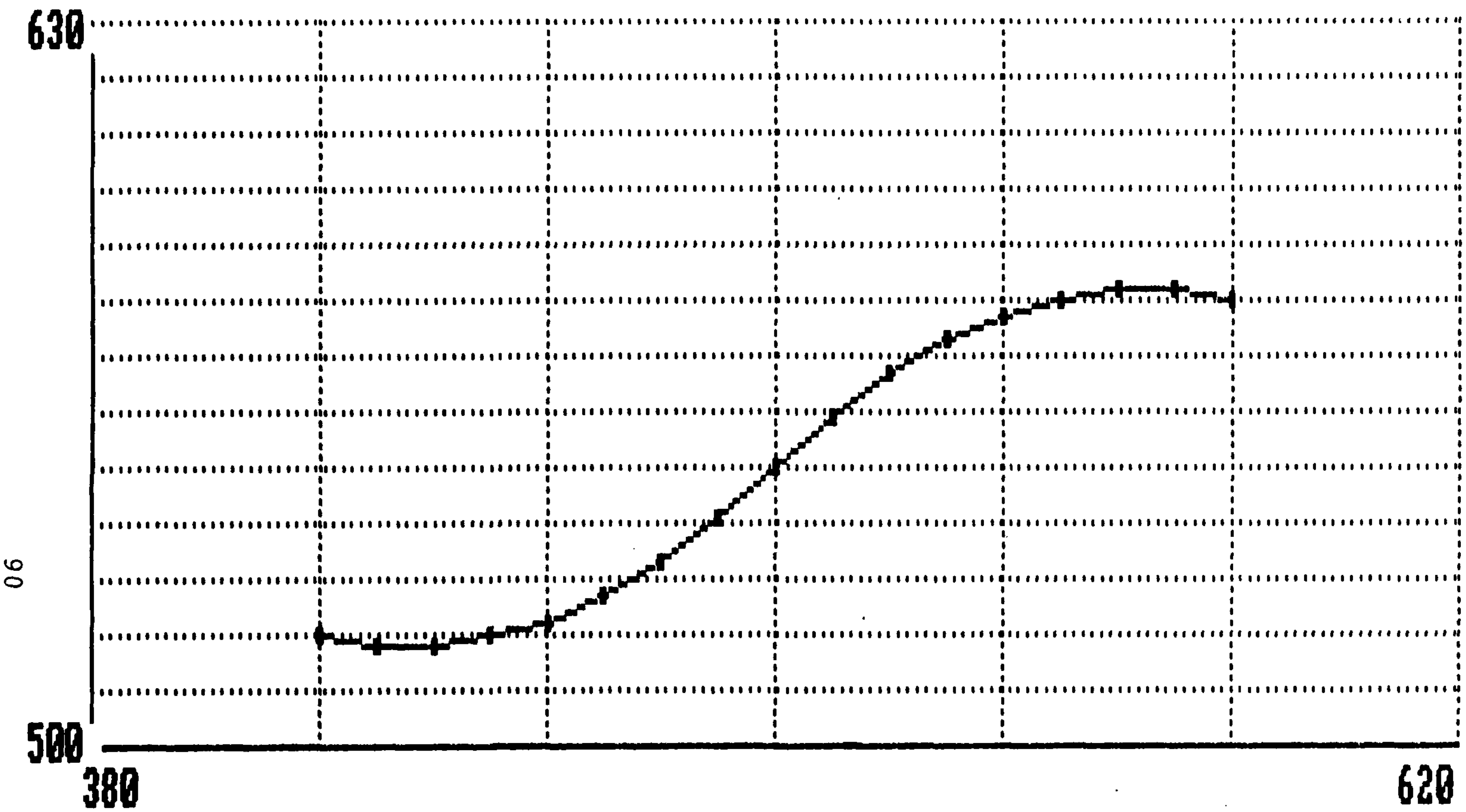


INCENTIVE SHARE CURVE
PROFIT VS COST



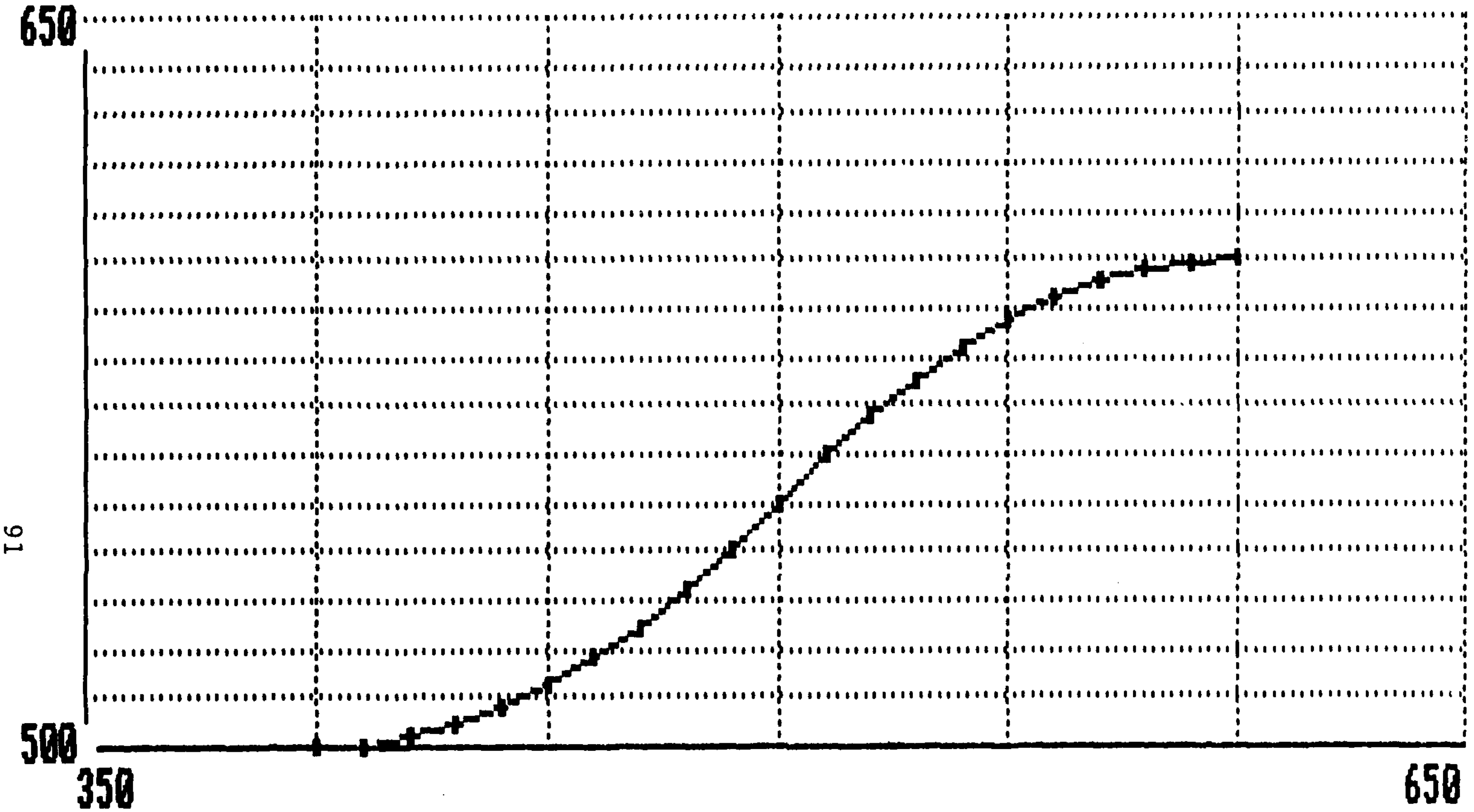
PRICE VS COST

(5% COST VARIANCE)



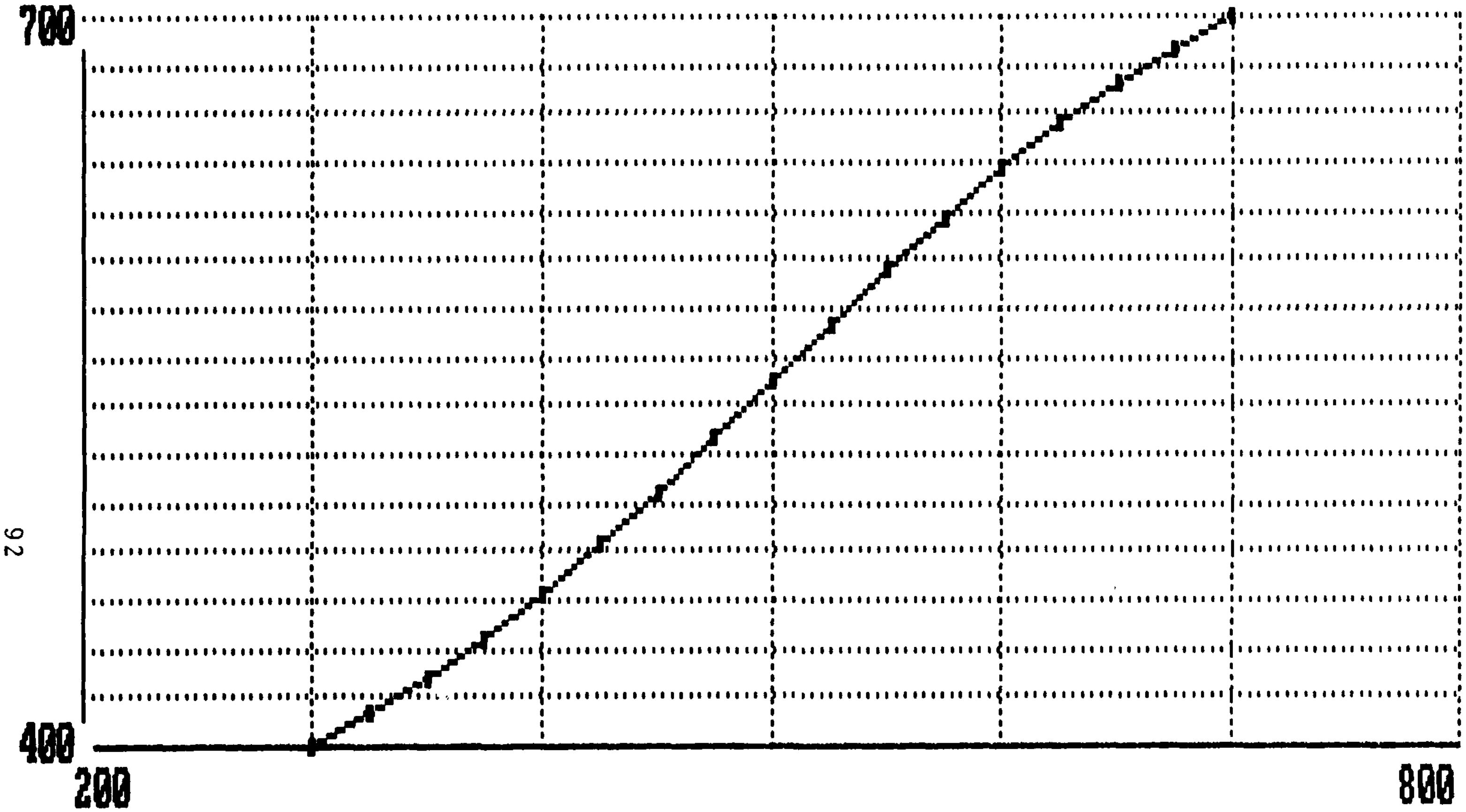
PRICE VS COST

(8% COST VARIANCE)



PRICE VS COST

(10% COST VARIANCE)



PRICE VS COST

(20% COST VARIANCE)

LIST OF REFERENCES

1. Kennedy, John J., Incentive Contracts and Cost Growth, Air Force Business Research Management Center, Wright Patterson AFB, Ohio, 1983.

2. Oppendahl, Phillip E., Understanding Contractor Motivation and Contract Incentives, Defense Systems Management College, Fort Belvoir, Virginia, 1977, p. 34.

3. Bertrand, Harold E., The Defense Industrial Base: Executive Summary, Logistics Management Institute, 4701 Sangamore Road, Washington, DC, August 1977, p. 7.

4. Dixon, Max Wayne, A Statistical Analysis of Deviation From Target Cost in NAVAIRSYSCOMHQ Fixed Price Incentive Contracts During the 1949-1965 Time Frame, Masters Thesis, Naval Postgraduat School, Monterey, California, 1973.

5. Scherer, Frederick M., The Weapons Acquisition Process: Economic Incentives, Graduate School of Business, Harvard University Press, Boston, Massachusetts, 1964.

6. Fisher, Irving N., A Reappraisal of Incentive Contracting Experience, Rand Corporation, Santa Monica, California, 1968.

7. Parker, Capt John M. Jr., and Belcon, Ltcol David L., "An Examination of Army, Navy, and Air Force Incentive Contract Outcomes," National Contract Management Journal, Vol. 6, No. 1, 1959.

8. Jones, J. E. Major, An Analysis of Incentive Contracts with Respect to Risk, Masters Thesis, U.S. Army Command and General Staff College, Fort Leavenworth, Kansas, 1971.

9. Touche, Ross, Cost Overruns in Government Contracts, Program Circular, Seminar & Conference Division, Washington, DC, 1985.

10. Roosin, Nathaniel, Advanced Concepts in Cost Estimating, Seminar, Technical Marketing Society of America, Sunnyvale, California, July 1985.

11. Kazanowski, A. D., A Quantitative Methodology for Estimating Total System Cost Risk, Space Division, Air Force Systems Command, Los Angeles, California, 1983, p. 43.

12. Anderson, Richard M., "Handling Risk in Defense Contracting," Harvard Business Review, July-August 1969.

13. Worm, George H., Application of Risk Analysis in the Acquisition of Major Weapon Systems, Air Force Office of Scientific Research, Southeastern Center for Electrical Engineering Education, Wright Patterson AFB, Ohio, 1980.

14. Jones, J. E., MAJ, USA, An Analysis of Incentive Contracts with Respect to Risk, Masters Thesis, Air Force Institute of Technology, Fort Leavenworth, Kansas, 1971.

15. Olkin, Gleser, and Derman, Probabiilty Models and Applications, MacMillan Publishing Co. Inc., New York, New York, 1980, p. 102.

16. Hays, William L., and Winkler, Robert L., Statistics Vol. I, Holt Reinhart and Winston Inc., New York, New York, 1970, pp. 484-486.

17. Ibid.

18. DOD/NASA Incentive Contracting Guide, October 1969, Chapter III.

19. Ott, Lyman, An Introduction to Statistical Methods and Data Analysis, Duxbury Press, North Scituate, Massachusetts, 1977, pp. 70-75.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee, Virginia 23801	2
4.	Department Chairman, Code 54Gw Department of Administrative Sciences Naval Postgraduate School Monterey, California 93943-5004	1
5.	LCDR Ray Smith, Code 54Sx Department of Administrative Sciences Naval Postgraduate School Monterey, California 93943-5004	1
6.	Prof David V. Lamm, Code 54Lt Department of Administrative Sciences Naval Postgraduate School Monterey, California 93943-5004	5
7.	LCDR Christopher M. McGrath Joint Cruise Missile Project Office Department of the Navy Washington, DC 20376	2
8.	Naval Air Systems Command Code 02 Department of the Navy Washington, DC 20376	1
9.	Naval Sea Systems Command Code 02 Department of the Navy Washington, DC 20376	1
10.	Administrative Sciences Curricular Office Naval Postgraduate School Monterey, California 93943-50004	1